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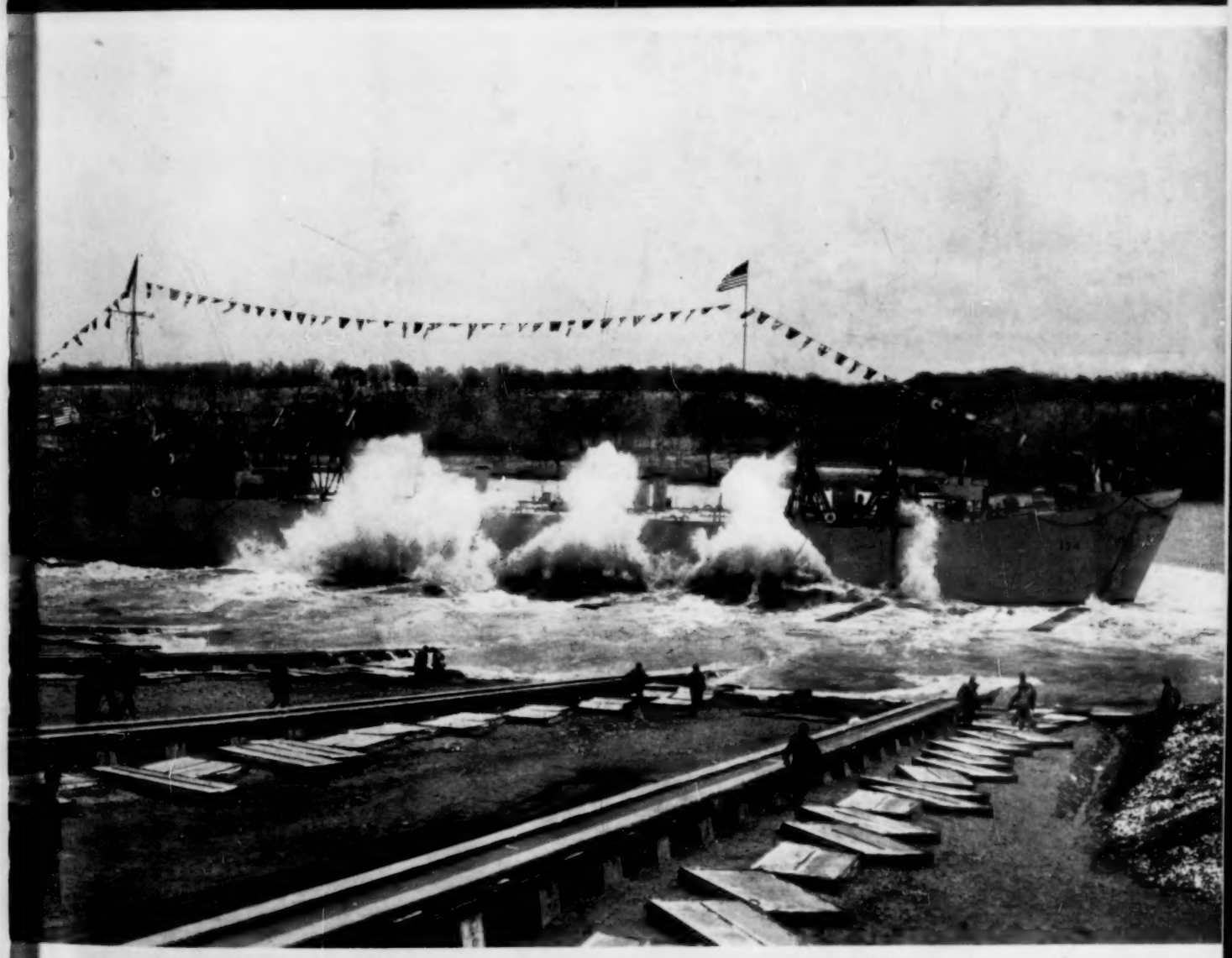

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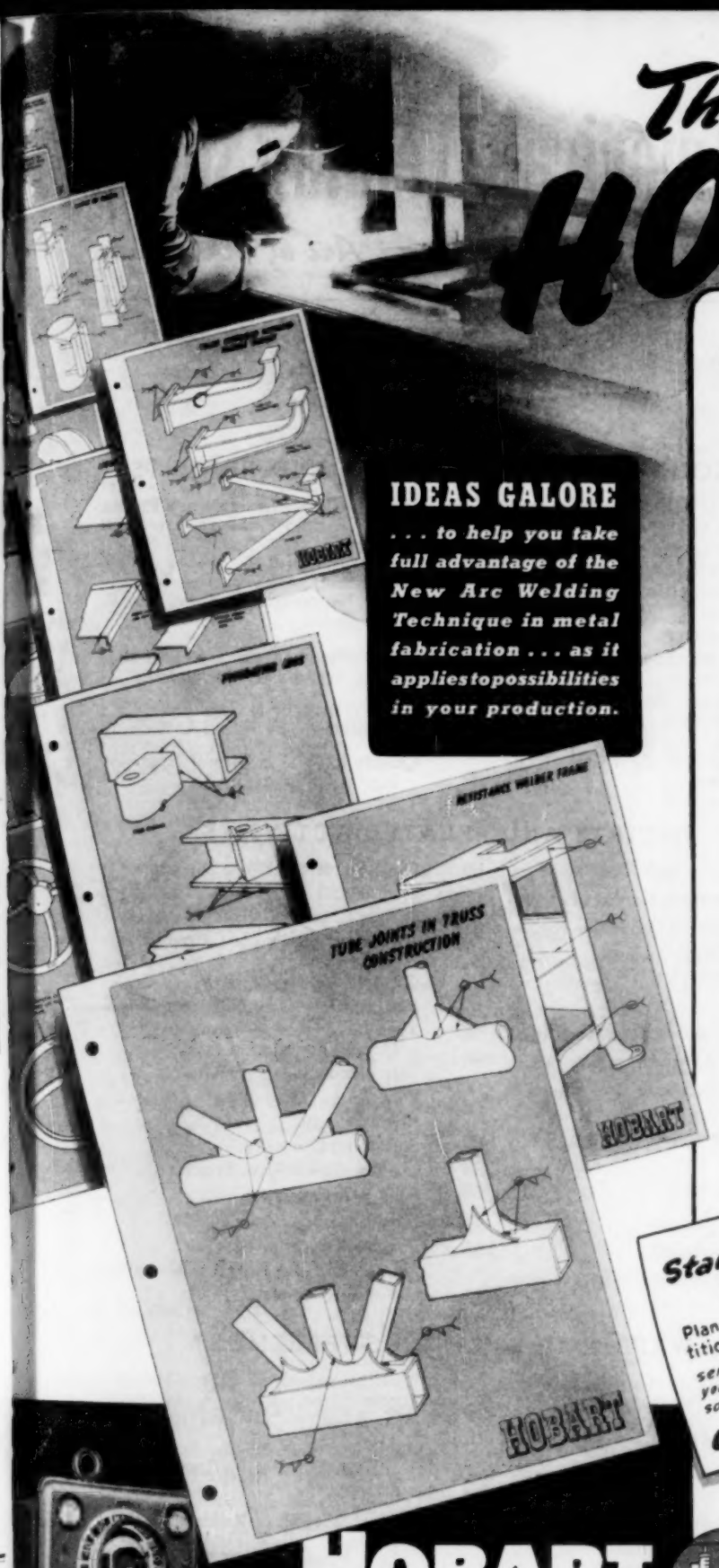

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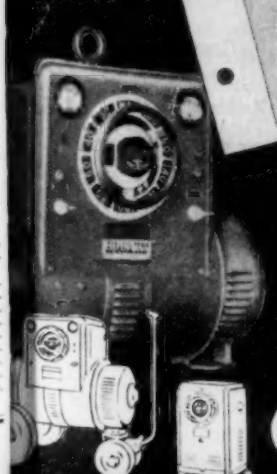

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Published for the Advancement of the Science and Art of Welding

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January 1944

VOLUME 23 NUMBER 1

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Better Welds Through Regulated Welding Current*

By B. Cooper†

IN THE development of resistance welding techniques, and in the extension of these techniques to cover broader scopes of welding, it has become increasingly important that we discover new and improved ways of controlling the variable factors that enter into the making of a good weld. It is important that this be done because resistance welding offers a high-speed, highly reliable method of metal fabrication whose value to industry and our war effort is measured in millions of dollars.

The purpose of this paper is to discuss one of the problems encountered, namely the maintaining or regulating of the welding current at its proper value in spite of variations in influential factors. The necessity of a current regulator has come about through the growth and extension of resistance welding into fields previously not covered, and in the introduction of industrial programs designed to improve the consistency and quality of the welded products. As a matter of fact, the current regulator has by its use, made possible the resistance welding of many products which formerly had not fallen within the scope of this type of welding.

The importance of the current regulator is emphasized by examining the following equation which is the expression for the heat developed in the welded area.

$$H = I^2RT$$

where H = heat developed in the weld.
I = welding current.
R = electrical resistance of the weld.
T = duration of current flow.

Since the welding current appears in this expression as a squared term, then any variation in the welding current will have a multiplied effect on changing the heat in the weld. For example, a 10 per cent change in welding current causes a 19 per cent variation in welding heat. Of course, the welding current is not the only factor which may change the welding heat, as the equation demonstrates. These other factors require equal care and attention. Control of the resistance at the section to be welded is accomplished by proper methods of cleaning, by use of correct electrode shapes and pressures, and by careful handling of material. Proper application of electrode pressure also produces a beneficial forging action. Electronic timing controls may be made sufficiently accurate for even the most precisely timed jobs. Once sufficient data is available for making the weld, the one remaining factor is that of setting and maintaining the welding current at its correct value.

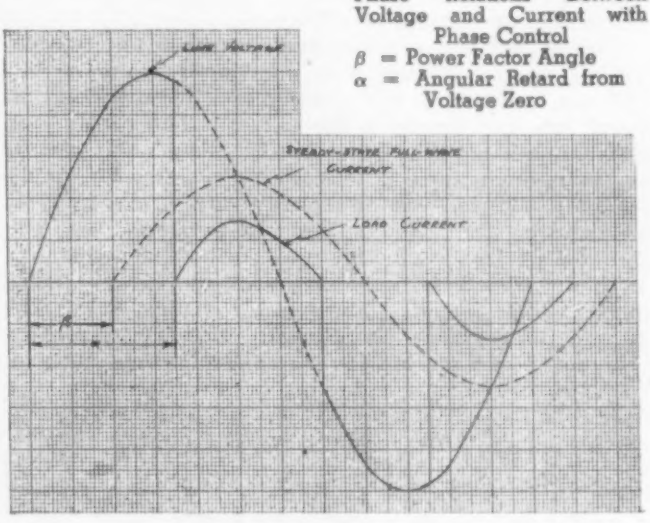
* Presented before the annual meeting of the AMERICAN WELDING SOCIETY, October 18 to 21, 1943, at Chicago, Illinois.

† Electronics Section, Industrial Control Engineering Division, General Electric Company.

Causes of Variations in the Welding Current

One of the most frequent causes of variation in welding current is a variation in the power supply voltage during the making of the weld. Since the welding current is directly proportional to the supply voltage, any change in the supply produces a proportional change in the welding current unless some compensations are made.[1,2] While the current regulator is not designed to maintain the supply voltage at its normal level, it is, however, capable of nullifying the undesirable effects of any variations in the supply voltage. Because of certain economic reasons or shortages in critical materials, it is sometimes not feasible to build a power supply system of sufficient capacity to withstand the severe short-time loads created by the welding machine, without having appreciable variations in line voltage. The application of a current-regulating device at such an installation permits high-quality, consistent welding comparable with the welding produced on a power line having only a few per cent regulation.

The second two causes of changes in the welding current can be considered together since very often they occur simultaneously. These two causes are either a change in the power factor of the welding transformer and load, or a change in the impedance of the transformer and load, or a combination of these two effects. That a change in impedance will cause a change in the welding current is an obvious fact, but why just a



Phase Relations Between Voltage and Current with Phase Control
β = Power Factor Angle
α = Angular Retard from Voltage Zero

Fig. 1

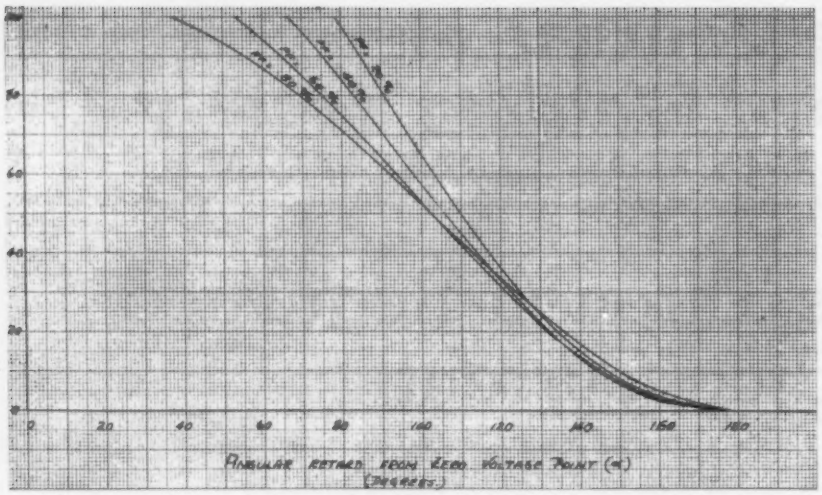


Fig. 2—Effect of Angular Retard on R.M.S. Current with Phase Control for Various Power Factor Loads

change in power factor alone can cause the current to vary, is perhaps not quite as obvious. On examining Figs. 1 and 2, which show characteristic curves for phase-controlled currents in loads of any power fact, it can be seen that for any given point of phase retard, the percentage current will vary with the power factor of the welding transformer and load.

This change in impedance or power factor may come about in several ways. First, as the upper or lower electrodes of the welding machine are moved to alter the shape or size of the secondary throat to fit a specific welding job, this change in geometry of the throat will change both the impedance and power factor. While such a change in secondary throat impedance can usually be compensated for by some manual readjustment of welding transformer taps or the heat control setting, it would nevertheless be much more satisfactory to have one given setting represent a given welding current irrespective of welder throat geometry. A more serious case is when a welding gun is used without concentric cable; then the mechanical movement and separation of the cables during welding would create a changing condition that could not be compensated for by manual readjustments. Any change in the arrangement of the secondary will cause a variation of the welding current, and regardless of how this change takes place the net result is that a larger secondary throat will require a greater secondary voltage to maintain a given welding current, or vice-versa.

The second and perhaps most frequent and troublesome cause for a change in the power factor or impedance, or both, is the introduction of magnetic material into the throat of the welder. The presence of the magnetic material immediately changes the secondary inductance, tending to make the welding load more reactive. At the same time, eddy current and hysteresis losses in the magnetic material projecting into the throat increase the effective resistance of the secondary. If these two effects occur in proper proportions, there may be no appreciable power factor change, but rather an overall increase in impedance. However, generally there is a power factor change, the change depending on which is greater, the inductive or resistive effect produced by the introduction of the magnetic material in the secondary throat. The power factor may then be made either more leading or more lagging than originally, by these changes. Generally, the resistive effect is greater making the power factor higher.

Still a third condition which exists is one where it is desirable to use the same welding machine to make welds which may alternately require using a welding gun connected in parallel with the secondary of the welder, or the main electrodes. This actually is a special condition of changes in impedance and power factor just previously described. Such a job would ordinarily require more than one heat control; each control would have to be adjusted differently for each welding job, and in general would require a certain amount of cut-and-try juggling to get identical results with the finished product. On a set-up of this type, the current regulator can maintain constant electrical welding conditions irrespective of the projection of material into the throat of the welder and irrespective of whether the weld is made between the main electrodes, or with the welding gun.

Some Present Applications

In one of the General Electric plants, it became highly desirable, in order to speed war production, to spot-weld many assemblies and parts of assemblies which had previously been either bolted together or welded by other means. Before such a program could be inaugurated, it was necessary to demonstrate to the Army and Navy that sufficiently high, and consistent quality-welding of these parts could be maintained on production lines. The part played by the current regulator in the "quality-control" program led to the immediate approval of the process, and convinced the factory welding engineers that it would be desirable to include one of these current-regulating controls with as many of the welding controls as possible.

On a second application, the successful welding of hollow steel propeller blades aided greatly in the war effort. In the welding of the blade, different amounts of steel projected into the throat of the welder at various times causing changes in the welding current which could not have been tolerated. This difficulty was completely removed by the addition of the current-regulating control to the standard welding equipment. (Fig. 3.)

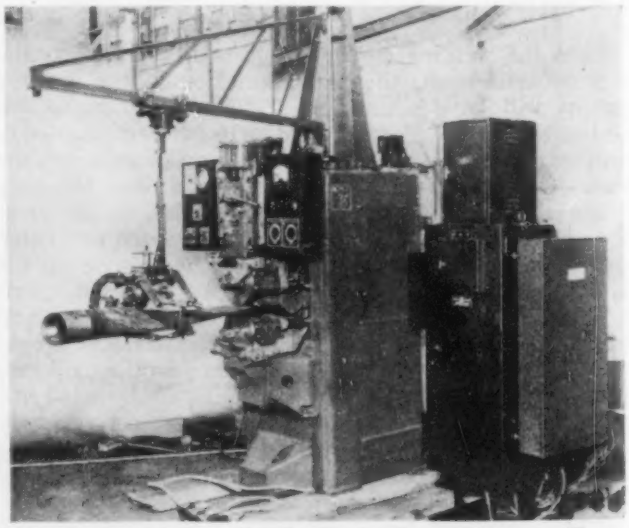


Fig. 3—Aircraft Propeller Set Up for Seam Welding. Electronic Timing Control with Current-Regulating Control (Panel at Top) Shown at Right

Fig. 4—G-E Current-Regulating Control Panel. Front View, Door Open

Another application was in the making of oil and gas drums, where at one time during the welding process, the entire drum projected into the throat of the welder. The variation in welding current coresponding to different positions of the drum in this particular case was about 40 per cent before the current regulator was installed, so a constant manual readjustment was required. The change in current was so great that without readjusting the current, the drum was burned severely at one point, while at another point, it was not even tacked together. The current regulator held the welding current to within 1 per cent of the normal value throughout the range with the result that a uniform weld was obtained at all points along the drum.

Still another application lies in the welding of a large steel-plate section where it is inevitable that various amounts of the plate will be projected into the throat at different times. The part played by the current regulator is so important that it may represent the difference between success and failure of mass production of these large irregular shapes.

Certain types of steels must be heat treated after they have been welded. Such post-heat treatments as are required can be made with the welding machine before the welded part is removed. Proper heat treating can be accomplished only by raising the welded part to definite specified temperatures. This means very accurate control of the welding current where any variation in the current during the heat-treating period might otherwise result in poor heat treating and low-quality welds. The current regulator thus insures quality welding and heat treating in mass production.

The matter of making welds with either an auxiliary welding gun, or between the main electrodes of the welding machine has already been described. These and many other similar applications lie within the scope of the current regulator.

Selection of Regulating Welding Equipment

The current regulator may be built as an attachment to be used in conjunction with the main welding control panel. The present types of regulators are designed to work with standard phase-controlled welding equipments. (Fig. 4.) It is absolutely necessary that phase-controlled panels be used because the current is regulated by means of automatically changing the phase-controlled current settings. If variations in the welding current occur only as a function of line-voltage fluctuations then a more simplified and less expensive control than the one described here may be used. This simplified type of control, known as a welding voltage-regulating compensator, will maintain the welding current to closer than 3 per cent of the nominal current setting for a plus 5 per cent to minus 25 per cent voltage change.

However, if variations in the welding currents occur as a result of impedance or power factor changes, in addition to possible voltage variations, then the current-regulator control described herein is recommended.

Phase Control Method of Current Adjustment

In circuits employing gaseous type tubes such as thyratrons and ignitrons, the average load current carried by these tubes is controlled by controlling the relative portion of each cycle during which the tubes are permitted to remain conductive. For example, if the tube is made conductive at a point early in the cycle, the current will flow for a large portion of the cycle as shown in Fig. 5*A*, making use of a large portion of the available power. On the other hand, if the tube is made conductive at a point late in the cycle, as in Fig. 5*B*, the current will flow for a correspondingly shorter portion of the time, and give a correspondingly lower rms. value of current. By varying the firing point of the ignitrons, the magnitude of the current carried by them is adjusted to any desired value. Again referring to Fig. 2, the effect of varying the point of firing during the cycle on the rms. value of current is demonstrated by these characteristic curves. The current regulator uses this principle as its basis of operation, automatically making any change in the firing point of the ignitrons that is necessary to maintain a constant welding current.

How the Current Regulator Works

In order to hold the welding heat at a constant value, it is necessary to keep the rms. value of the welding current constant. This is done by placing a current

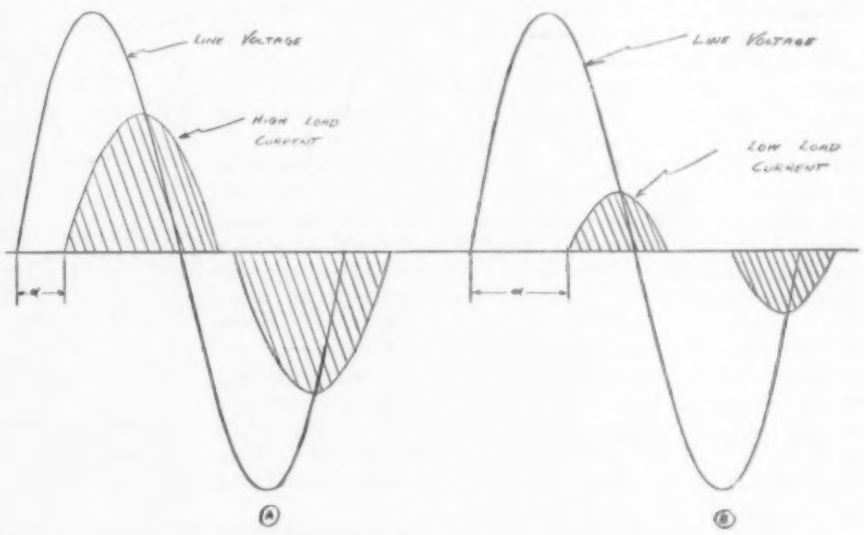


Fig. 5—Phase Control Method of Current Adjustment

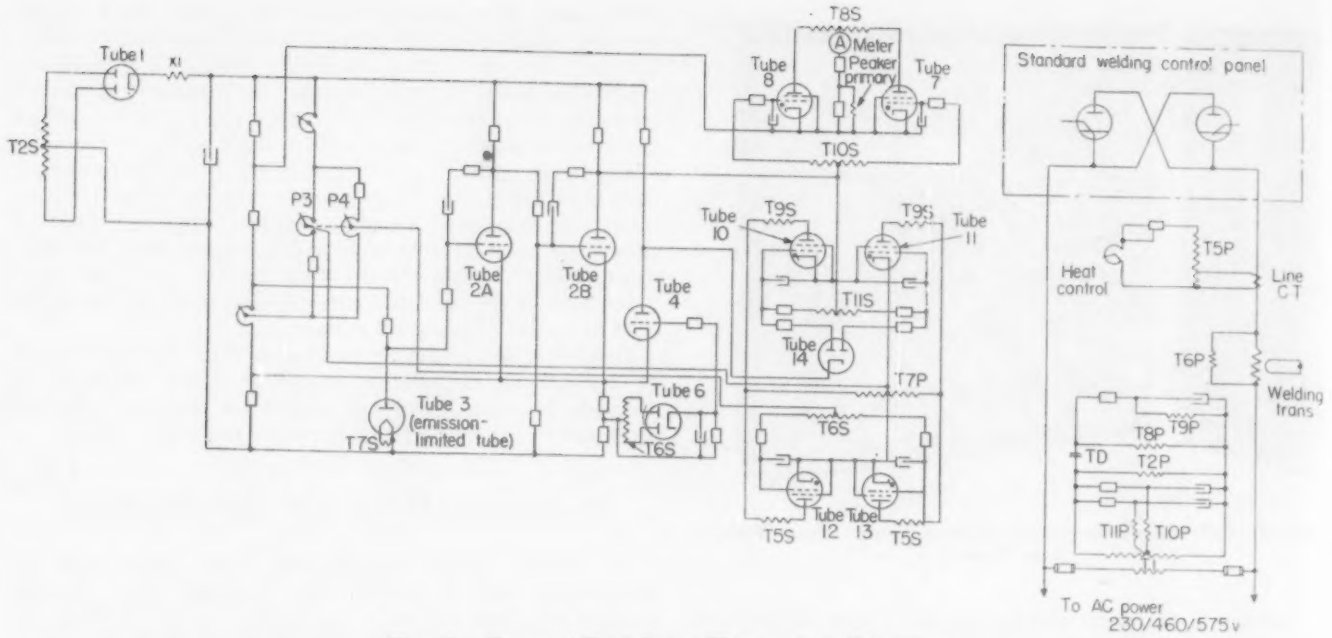


Fig. 6—Current Regulator Elementary Diagram

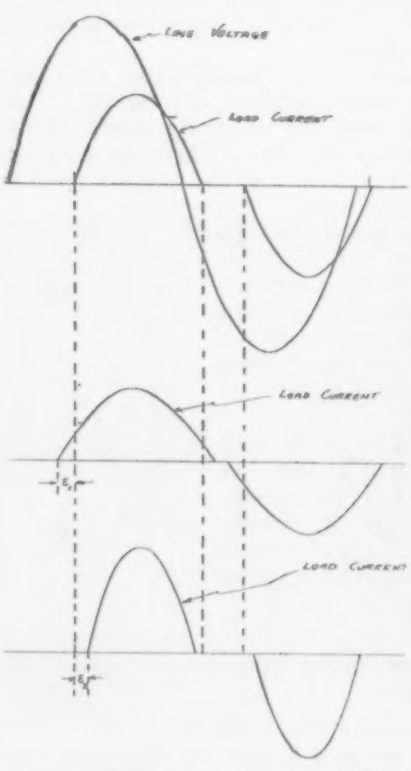
transformer in the line supplying the welding transformer and using the secondary current output to control the welding current regulator. The regulator consists of: first, a special tungsten filament rectifier tube which measures the rms. welding current; second, a comparison and amplifying circuit for comparing this value of welding current with a normal value and giving a signal proportional to any deviation from normal; and finally, a phase-shifting circuit for controlling the power ignitrons in the main welding control. Figure 6 is a simplified circuit diagram of the current regulator.

The heart of the regulating system is the tungsten filament rectifier tube whose filament is heated by the current from the current transformer and whose output is proportional to this current. Since an identical facsimile of the actual welding current from the current transformer heats the filament of this rectifier tube, any variation in the heat at the weld caused by current changes will produce a like variation in the temperature of the rectifier filament. The output of this rectifier tube which is operating in an emission-limited state will be directly proportional to the filament temperature and to the heating value of the welding current, and will therefore, be a true measure of the rms. welding current.

The output of the emission-limited tube is compared with a reference voltage appearing across part of the voltage divider on the d.-c. control supply. This reference or comparison voltage is held essentially constant by virtue of the voltage stabilizing action of transformer (T2), so that it will not be affected by variations in the control voltage. The difference between the output voltage of the emission-limited tube and the reference standard is applied to the grid of the first stage of a two-stage amplifier. The d.-c. voltage of the two stage amplifier is used as the d.-c. component in an a.-c., d.-c. phase-shift system employing thyratron tubes (7 and 8) and a transformer (T8) as a source of excitation for the peaking transformer on the main welding panel. This peaking transformer produces a peaked output voltage whose phase corresponds to the point of firing of Tubes 7 and 8. The peaked output voltage controls the firing tubes on the main welding panel and hence controls the power ignitrons.

Regulation of the welding current is accomplished by changing the point of firing of the ignitrons as illustrated in Fig. 7. If the welding current tends to decrease, the firing point is automatically moved to a point earlier in the cycle, thereby permitting the ignitrons to carry current over a larger portion of the cycle. If on the other hand, something attempts to make the current increase, this firing point is retarded, thereby reducing the time of current conduction per cycle and decreasing the current to normal. The new firing point is chosen by the regulator so as to make the rms. value of welding current essentially constant.

Following through one regulating operation, let us assume that the welding current is higher than the nominal setting. Under this condition, the filament



7A—Normal line voltage and load current. Phase relations shown for normal lagging power factor load.

7B—If the magnitude of the current wave is reduced, as might result from either a drop in line voltage or increase in load impedance, or combination of these effects, the R.M.S. value of this half cycle of current will be restored to normal by advancing the point of firing by the amount (ϵ_1).

7C—If the magnitude of the current wave is increased, such as might result from effects opposite those of (7B), the R.M.S. value of this half cycle of current will be restored to normal by retarding the point of firing by the amount (ϵ_2).

Fig. 7—How the Regulator Maintains Constant R.M.S. Current

of the emission-limited rectifier (Tube 3) will be hotter than normal, and will cause the output of this tube to be greater than normal. The difference in voltage between the reference standard, and the output of Tube 3, will make the grid of the first amplifying tube more negative. The resulting action of the two-stage amplifier is that the plate (Point 19) of the second stage moves more negative, causing the peaker exciting tubes to be phase retarded. This in turn, retards the point at which the power ignitrons are made conducting and thereby returns the current to normal.

Any type of regulator that controls the current by changing the point of firing, is obviously limited to operation below 100 per cent or less than full sine-wave current conduction. Once full sine-wave conduction is reached, no further regulation of the weld current can be expected. At points below the full sine-wave condition, the regulator will hold the welding current to within ±2 per cent of the nominal setting, for changes that would otherwise have produced a ±20 per cent variation in welding current. And ± 20 per cent change in circuit impedance is by no means the outside limit of regulating possibilities. This regulator will hold the current essentially constant over a possible 5 to 1 change in current, having a regulating error over this range in the order of 5 per cent.

Switching of Emission-Limited Tube Filament

Since welding current does not flow continuously in the welding line, the filament of the emission-limited tube would be heated only intermittently if some other means were not provided. It is necessary to have the filament of the emission-limited tube already near its normal operating temperature in order to eliminate any appreciable thermal lag which would hinder fast and accurate control at the start of each weld. Therefore, this control provides a stand-by source of voltage to excite the filament of Tube 3 when no line current is flowing. This procedure allows the emission-limited tube filament to be preconditioned according to the magnitude of the stand-by source of voltage. At the instant welding current does flow, the filament of Tube 3 is switched from the stand-by source to the voltage supplied by the line-current transformer. The regulator then performs its regulating duties as previously described. However, the initial cycle of weld current will have a magnitude determined by the temperature of Tube 3 at the instant prior to the starting of the weld. By controlling and regulating the filament current prior to the start of the weld, the initial cycle of weld current may be made any value desired. By use of the tandem potentiometers P3/P4, and the milliampere meter, the starting current may be easily set. Usually, it is most desirable to set the first cycle to be as near as possible to the other cycles that will follow. This can be done to an accuracy of approximately 5 per cent which should be quite satisfactory for most cases.

Since the starting cycle is set at an arbitrary value to be approximately the same as the following cycles of welding current, it is apparent that should the duration of the welding cycle be made too short, any error in the manual presetting of the starting weld current will become an appreciable part of the total welding heat. For this reason, minimum "on" or weld time of not less than six cycles is recommended. Also, in the switching of the emission-limited tube filament from the current-transformer voltage back to the stand-by source, a small transient is introduced in the control circuit. In order to be sure this transient has completely died away, the minimum "off" or cool time during seam or pulsation welding should be not less than four cycles.

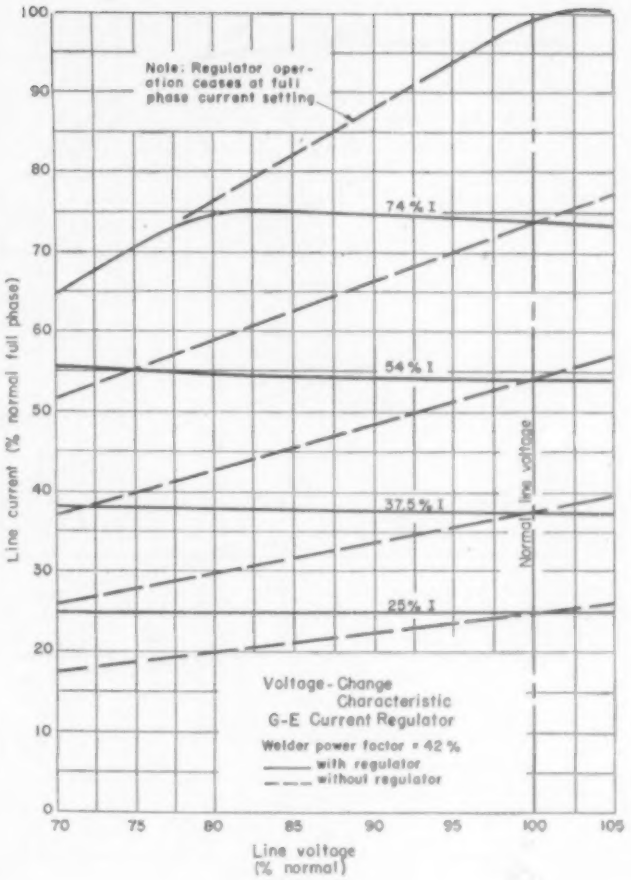


Fig. 8

"Memory" Circuit and Its Use

In the making of long seam welds such as a longitudinal seam on a drum or plate moving into a deep-throated welding machine, the change in impedance comes in gradual steps and in a uniform manner. For this type of set-up it would be desirable to not have to start at the manual setting described in the previous paragraphs but rather to provide some means of automatically changing the starting point of the beginning cycles of each spot in such a manner that less error is introduced. A "memory" circuit has been developed which automatically records the phase setting last held by the current regulator, and starts the next spot at the same heat setting as was held on the last cycle of the previous spot in the seam. This assumes that the current regulator was operating and had held the current correctly at the end of the last spot, so that as the welding wheels index or move to the next spot, only a very small change in impedance will have taken place. If the beginning cycle of each new spot is at the same heat value as the last cycle of the previous spot, then it will be more nearly correct than any manual adjustment could be. As the phase setting is changed to compensate for changes in impedance, this "memory" circuit automatically changes the starting point to the new phase position as determined by the regulator. Through such a procedure, the current is maintained very closely on even the first cycles of each spot.

This "memory" circuit is arranged so that when it starts up initially, it gives a retarded phase setting which is brought up to correspond with the correct setting as determined by the regulator, within 2 to 3 cycles. The length of "memory" may be any value up to 1 minute. By employing a more elaborate filament

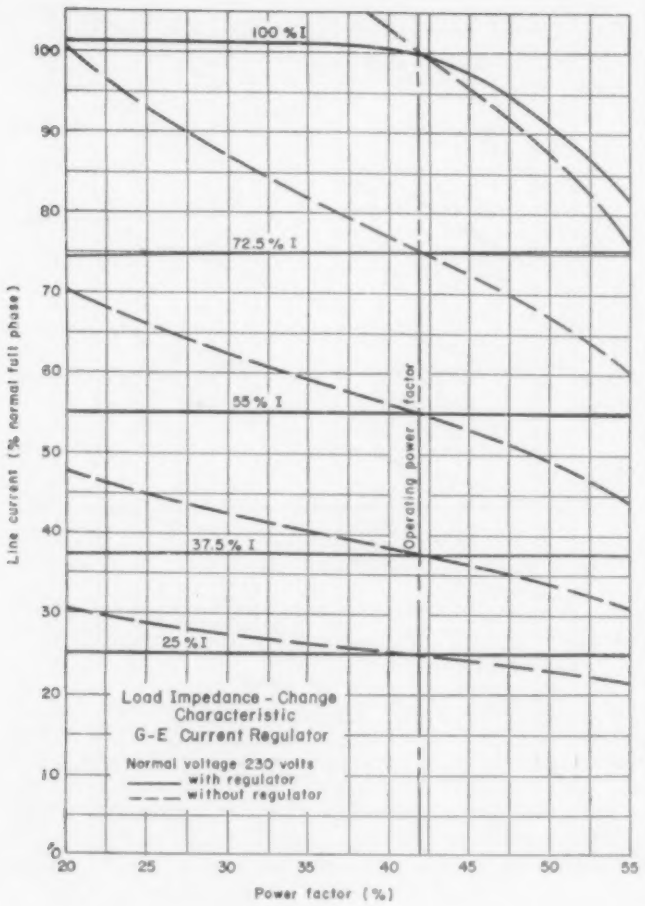


Fig. 9

switch system with this more accurate method of adjusting the initial cycles of starting current, the welding cycle limitations may be reduced to 2 cycles "on" and 2 cycles "off" in a seam weld. The use of this circuit in a seam welding offers great possibilities for high-quality seam welding where, hitherto, large changes in impedance have made the job extremely difficult.

Operation Features

The ranges over which the current regulator is effective in maintaining a constant welding current have already been discussed. Typical curves indicating operating characteristics when voltage changes are encountered, or when impedance and power factor changes occur are given in Figs. 8 and 9. The speed with which these corrections are made is extremely fast; for example, should a 20 per cent change in current occur due to some instantaneous change in impedance or voltage, the current will be returned completely to normal by the start of the third cycle following the circuit disturbance.

Extension to Series Capacitor-Improved System

While at the present time, no actual installations have been made of current regulators on series-capacitor welding systems, such an installation would require only a few minor changes in the standard control to adapt it to the new welding system. Experimental set-ups have been made and satisfactory operation accomplished.

The response of the regulating control will be much the same as on the welding systems without the series capacitors except that the speed of correction will be dependent to some extent on the electrical constants of the welding system. The reason for this is that an appreciable time (in the order of a few cycles), will be required to change the pre-charge of the series capacitors to the proper value. Along this same line, it will be necessary that the welding control to which the current regulator is applied, have the ability always to start the weld with a current flow of one polarity, then allow an even number of half cycles to flow, and terminate the weld with a cycle of current flow of polarity opposite to the initial starting cycle. If this is not done, the series capacitors may possess the wrong polarity charge at the beginning of the cycle with the result that a uniform welding current will not flow until the proper pre-charge on the series capacitor has been built up. This does not appreciably limit the application of the current regulator on series capacitor systems, because nearly all of the welding controls furnished for series-capacitors welding systems are capable of the type of control mentioned above.

Summary

The introduction of the current regulator as an auxiliary resistance welding control to be used in conjunction with standard welding control represents just one more step in our quest for more efficient and reliable methods of production. Like many other new devices, the current regulator not only allows old jobs to be done more satisfactorily, but opens new and fertile fields for the extension of resistance welding. A few of its applications have been described briefly, but these by no means cover the entire scope of application. In conclusion, it can safely be said, that the importance of the current regulator will become more and more evident as its abilities become better known among welding engineers.

Practical Design of Welded Steel Structures

By H. M. Priest

An attractive booklet of 150 pages bound in cloth covers with subject index. This book will be of great assistance to those concerned with the design, inspection or the welding of steel structures such as buildings and bridges. Price $1.00. American Welding Society, 33 W. 39th Street, New York 18, N. Y.

Electronic Control of Gas-Cutting Machines*

By R. D. McComb†

ONE of the most important considerations in the design and operation of gas-cutting machines is that of guiding the machine smoothly and accurately about the template or drawing. A number of different types of control have been developed for this purpose utilizing paper, plywood, steel and other materials for the template, and using magnetic, spindle, track-type or simply manual tracing devices on the machine.

Each of these types of control has a definite place in the gas-cutting field, depending upon the number of pieces to be made from a given template, and the type of work and accuracy required.

The control described in this article is designed to automatically guide the machine completely around a template, which consists of a pencil drawing on white paper, absolutely independent of the operator once the cut has been started.

Although the control itself is electronic, the operation is described in non-electronic language and is explained by the use of diagrams which can easily be followed by anyone familiar with machine gas cutting.

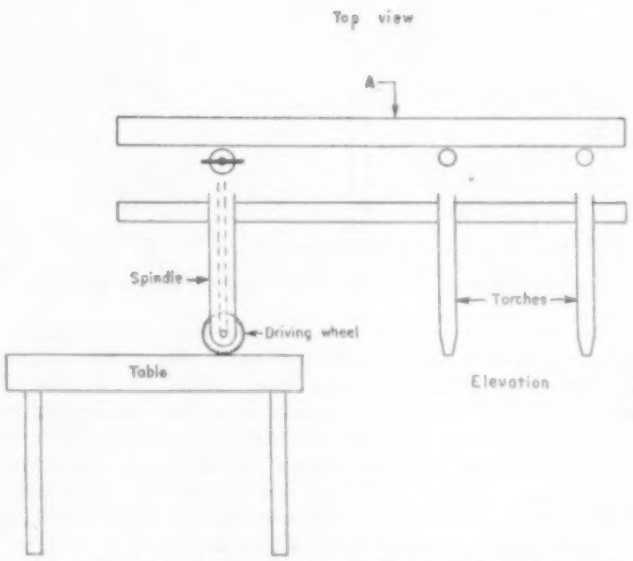


Fig. 1—Essential Parts of Gas-Cutting Machine Before Adding Electronic Control

Results Obtained

The use of this control will do much toward improving the quality and reducing the amount of scrap and extra work when applied to most gas-cutting jobs. The operator is relieved of the responsibility of guiding the driving wheel around the template so that he may spend his time to better advantage planning the next cutting job, and adjusting the torches or cutting speed if required during the cut.

One of the most important factors in reducing cost and increasing production is that of making each part exactly like the preceding part. This control eliminates the human error and makes 100, 1000 or as many pieces as are required, each one free of human error. This greatly facilitates inspection of the work, as the inspector can simply measure one piece of each lot and be assured that all of the remaining pieces are of the same dimensions.

In many cases, a saving of space and machines used to make templates, as well as personnel, may be effected because of the ease with which templates for this control are made and stored. The template simply consists of a piece of paper or white cardboard, upon which is drawn the shape which it is desired to reproduce. This may be done in heavy pencil, or in ink. Pencil is generally preferred since many of the templates are done on vertical drafting boards. Corrections can also be made more easily in pencil. In order to obtain a more permanent template, it is possible to use a narrow ink line backed up by a wider pencil line, or to use a striping device to make a wide ink line. Spraying templates with a thin coat of clear lacquer will help to prevent soiling of templates due to handling and dusty atmosphere.

Blueprints or black-and-white prints may be used as templates if the errors due to shrinkage of the paper and slippage when passing through the blueprint machine are not objectionable. The reduction of labor and machinery required in making the template, the savings in template material and the ease with which these templates may be stored, all tend to reduce the over-all cost of machine gas cutting.

Description

Figure 1 shows a sketch of a portion of a gas-cutting machine. Member *A* may be the tracing arm of a pantograph type of machine, or the cross carriage of the two-track type of machine. In operation, this member will always remain parallel to the east-west line (top view), although it may be driven in any direction by the driving wheel.

The driving wheel is rotated at a constant speed by a driving motor, not shown on the diagram. The speed of this driving wheel is constant, although the operator may steer it in any direction by rotating the spindle.

The gas-cutting torches are mounted on the same member, so that they exactly follow the motion of the spindle supporting the driving wheel. In other words, this machine is simply a standard gas-cutting machine arranged so that the operator can guide it manually about the template.

Figure 2 shows this same machine with a steering

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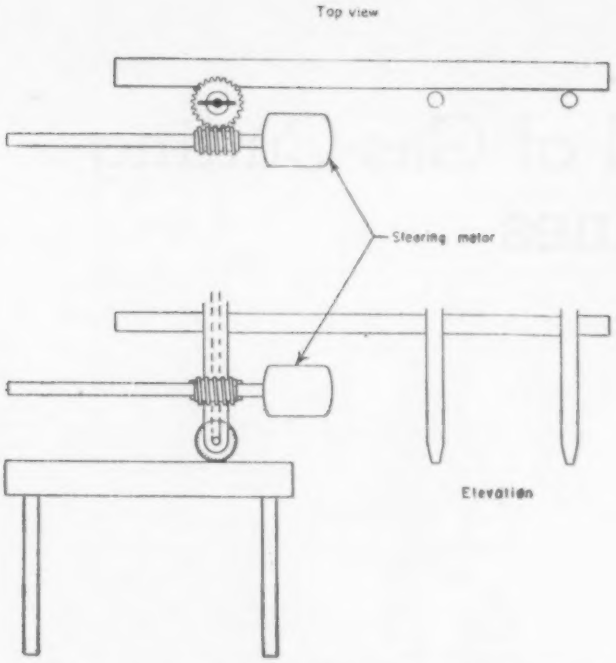

Fig. 2—Addition of Steering Motor to Gas-Cutting Machine

motor added, geared so that it may rotate the spindle in order to guide the machine. This motor simply performs the function formerly done by the operator, namely, that of rotating the driving-wheel spindle so that the driving wheel is guided in the proper direction.

In Fig. 3, another gear has been added to the steering motor shaft, and a drum, *B*, is geared so that it rotates with a ratio of 1:1 with the driving spindle.

Figure 4 shows a close-up of this drum which has a lens, *D*, mounted a short distance away from its center of rotation.

The drum is supported in bearings so that it may rotate about center line *XY*. The light source and lens *C* flood the entire bottom end of this cylinder with light. Lens *D* collects some of this light and projects it in the form of a small spot on the paper template at point *E*.

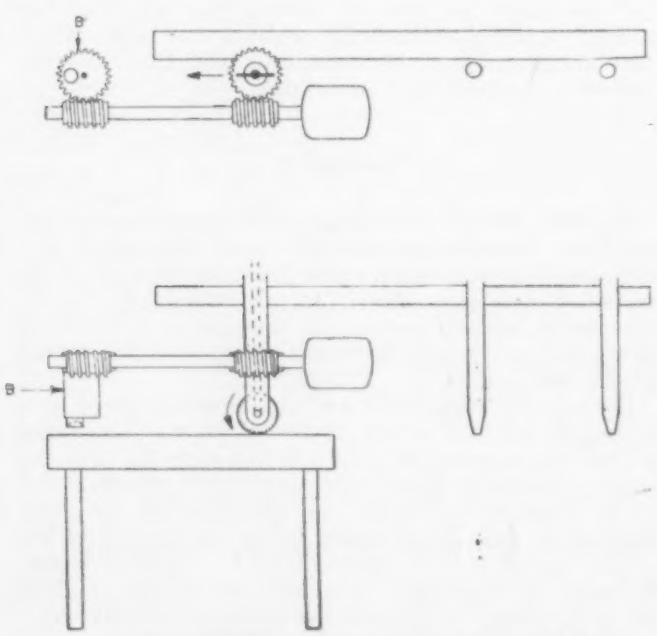

Fig. 3—Addition of Moving Parts of Electronic Control Optical System to Gas-Cutting Machine

One or more phototubes are mounted so as to receive the light reflected back from the template. This reflected light causes an electrical signal to be produced which is proportional to the amount of light reaching the phototubes.

Since the amount of light which reaches the paper at point *E* is constant, the amount of light which reaches the phototube depends upon the surface of the paper at point *E*. If this is plain white paper, considerable light will reach the phototube and its electrical signal will be fairly large. If a black line is drawn on the paper at point *E*, much of the light received from the optical system will be absorbed by this black line. Therefore, the amount of light reaching the phototube, and the phototube's electrical signal in turn, will be small.

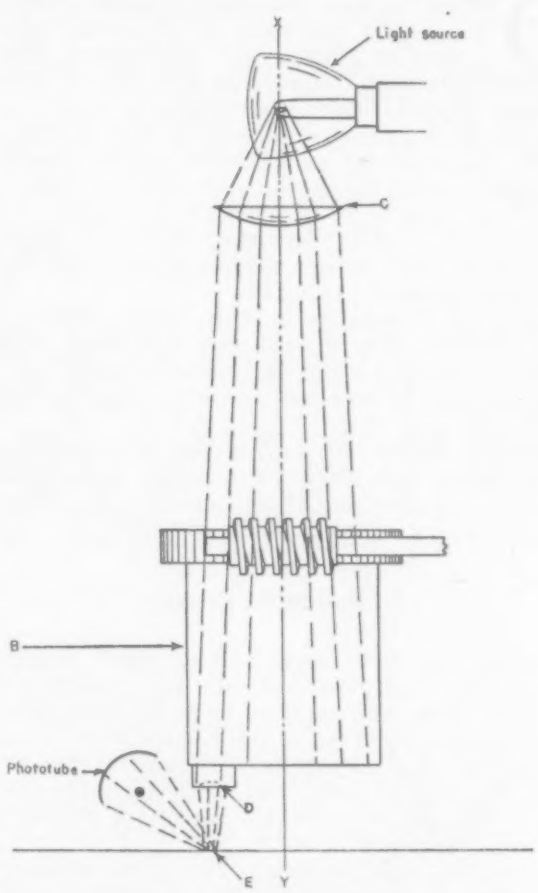

Fig. 4—Details of Optical System

Operation

The position of this small spot of light, *E*, when the control is following along a straight line is shown in Fig. 5. The control is adjusted so that the steering motor is at rest when the spot of light is half on the black line and half on the white surface of the template adjacent to the line. If the spot of light moves in either direction away from its correct position as shown in Fig. 5, a signal is given to the steering motor to return it to its proper position. The circuit is arranged so that if the spot should approach closer to the line, as shown in Fig. 6, both the optical system and the driving spindle will be rotated in the counterclockwise (top view) direction. If the spot should tend to leave the line and, therefore, strike the white paper surface, as shown in Fig. 7, the optical system and driving spindle will move in a clockwise direction.

As shown in Fig. 8, this response is not limited to

merely one position of this spot; the control can continue to follow around a circle, or other such figure, as many times as required. When following the curved line in Fig. 8, the steering motor is continually given a slight signal, due to the fact that the spot will always be traveling in the direction indicated by the driving wheel, and would therefore tend to leave the edge of the curved line if the steering motor did not turn the driving spindle clockwise.

Therefore, when following a curved line such as this, the spot will not quite be centered on the line, but will follow in such a manner that slightly more of its area is on the white paper template than is on the black line. In that way a slight signal is continually given to the steering motor so that the control is smoothly turned around the circle and produces a smooth, clean cut.

The action of the control when steering the machine around a square corner is shown in Fig. 9. The spot approaches the corner as shown in *a* and *b*. In *b*, it is just beginning to leave the straight portion of the

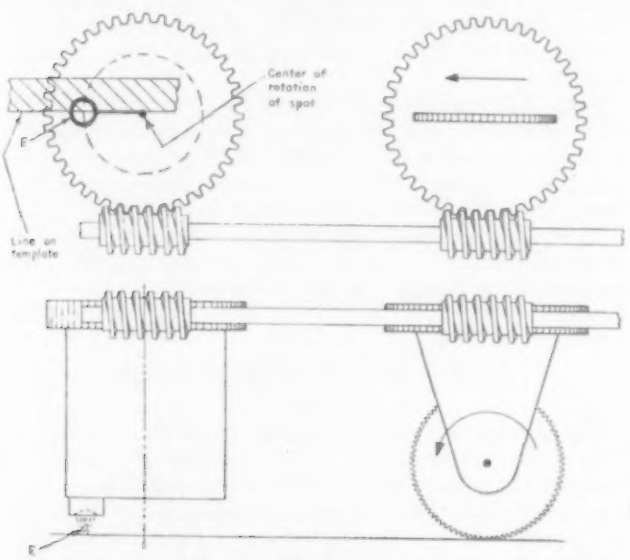

Fig. 5—Control Following Along Line in Direction of Arrows

vertical line, and therefore, the phototube is beginning to receive more light than it received in *a*. By the time the driving wheel has advanced the carriage to the position shown in *c*, the steering motor has begun to rotate the optical system and the driving head, and will continue to do so while the spot advances through the position shown in *d*. As shown in *e*, the control will position itself, with the spot approximately half on and half off of the black line of the template, and, due to the inertia of the machine carriage, the true position of the torches may pass slightly beyond the new line of motion as shown in *f*.

Accuracy

As can be seen from Figs. 8 and 9, the true position of the torch does not correspond with the true position of the spot when going around a sharp curve or corner. If the machine is traveling quite slowly, as would be the case when cutting heavy material, the tendency of the driving wheel to skid after the control has turned the spindle through 90° will be very small, and the cut obtained will be somewhat as shown in Fig. 10. If, however, the machine is operated at high speed, the machine might tend to skid beyond its proper position, and the cut obtained would be somewhat as shown in Fig. 11.

Fig. 6—Spot Too Far on Black Line: Control Turns Spot and Driving Wheel Counterclockwise

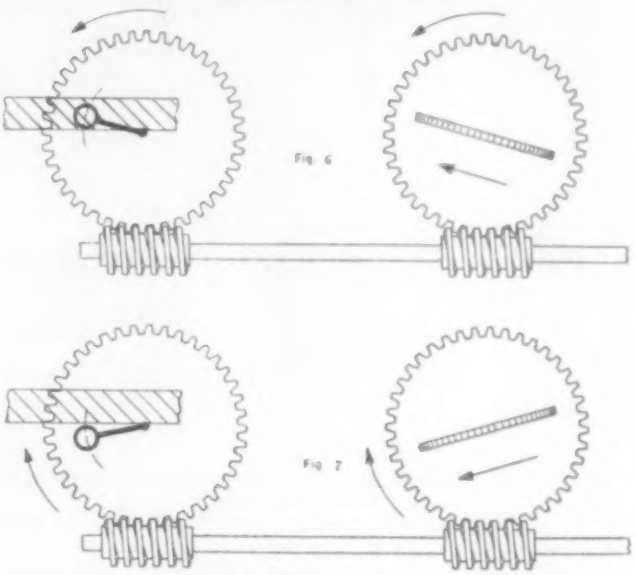

Fig. 7—Spot Too Far on White Surface: Control Again Returns Spot to Position Shown in Fig. 5

Most normal cuts will fall somewhere between the two extremes and will, therefore, produce the effect shown in Fig. 12, which consists of a slight rounding off of the corner, plus a slight raised spot on the top surface of the cut. It should be noted that these drawings are enlarged and the error is exaggerated in order to show the result more clearly.

However, the effect of these two errors is negligible. The distance from the center of rotation of the spot to the spot, is never more than approximately $^1/_8$ in. For many cases, this distance may be as small as $^1/_{16}$ or

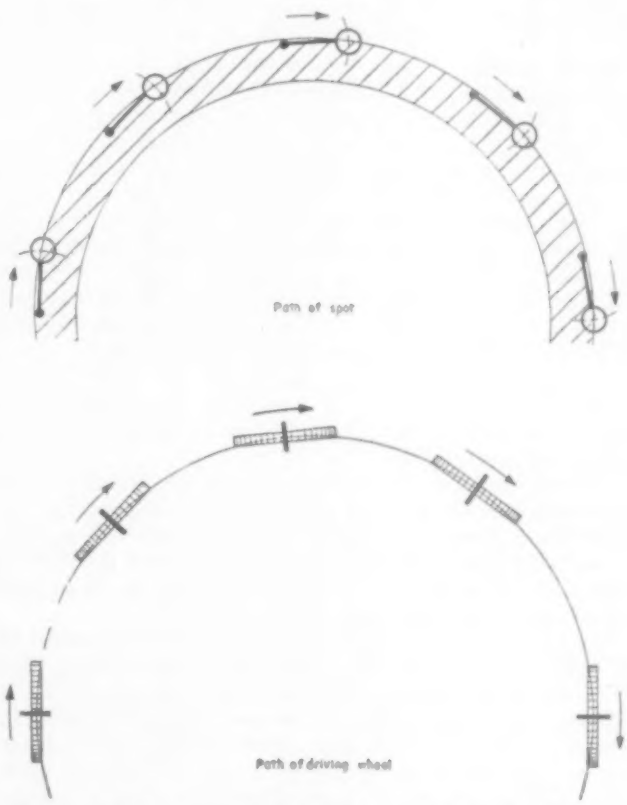

Fig. 8 (Greatly Exaggerated)—Operation of Control in Following Along Curved Template

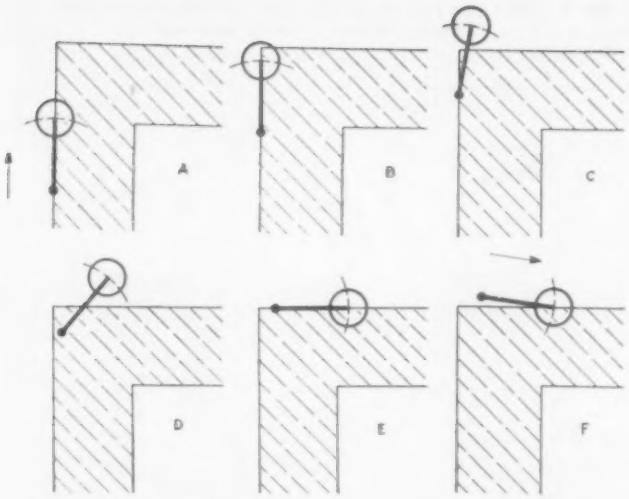

Fig. 9 (Greatly Exaggerated)—Operation of Control in Following a Right-Angle Corner

$^1/_{32}$ in., and therefore, this error will be correspondingly reduced.

If the distance between these two points were the *maximum* value ($^1/_8$ in.), then the error as shown in Fig. 12 would be $^1/_{32}$ in. or less. However, in most cases it will be found that the small projection, which is located on the top flat surface of the cut, will be partially burned off, due to the fact that the torch heats this material on the trip up along one side of the template and, as it turns to follow the new path along the top of the template, this material (which has already been heated to quite a high temperature) is burned off easily. Therefore, the error involved will usually be even less than this $^1/_{32}$ in.

Theoretically, it would be possible to change the radius of rotation of the spot, so that for high-speed cutting this radius would be fairly large, and for cutting on heavy stock at low speed, it would be very small. In actual practice, it has been found that an intermediate adjustment will be satisfactory for almost all of the work that is encountered in machine gas cutting today. If it is necessary to secure more precise operation, the template may be modified slightly, as shown in Fig. 13, so that a very nearly square corner may be obtained.

The diameter of the small spot of light on the paper is about $^1/_{16}$ in. Therefore, by the time the spot has moved $^1/_{64}$ in. away from its correct position, well over half of the maximum available signal has already been applied to the motor. This means that when following a straight or slightly curved line the error will, in most cases, not exceed $^1/_{64}$ in. at most.

In actual operation, it has been found that these errors are well within the permissible tolerances for all work encountered yet.

Since a full-sized template is used, the accuracy with which templates can be drawn is well within the permissible tolerance. Due to the fact that the machine constantly compares the torch position directly with the template, cumulative errors due to the driving wheel slipping are not present.

In addition to the fact that the error involved in the system is so small, there is one feature which contributes materially to this accuracy and speed of response, and that is the smoothness of operation of the control. The control does not provide an "off-on" signal, but instead provides a signal which varies smoothly as the spot is moved from its correct position to a position on either the black line or the white paper. Therefore, it provides a correction which is approximately proportional to the amount of error. This type of control, together with an anti-hunt circuit which is included in the electrical circuit of the equipment, combine to provide a control which rotates the spindle around a corner much more rapidly than could be done by hand, and yet maintains better accuracy than that obtained under manual control. The speed of rotation of the driving spindle when allowed to rotate freely is approximately 100 r.p.m., or almost two complete revolutions every second. Therefore, when the driving wheel approaches a corner, it is turned to its new position very rapidly. This makes it possible to follow intricate shapes with very good accuracy.

Conclusion

The control described here is able to reproduce, with excellent accuracy, any shape produced by a gas-cutting machine of the pantograph or two-track type. The electronic circuit and the optical system are all completely enclosed, so that they are protected from the dirt and abuse usually encountered in this type of manufacturing.

Both the quality and quantity of machine gas-cut parts are improved, because of the accuracy, speed of response and ease of operation of this control. These features, together with the simple template requirements, assist in reducing the cost of gas cutting.

It is expected that this type of control will soon become well known in many other manufacturing fields, in addition to the gas-cutting industry.

Electronic Control Circuit Details

The electronic control circuit is shown in Fig. 14. Tube 1 is a rectifier tube which supplies d.-c. power for the phototube and for amplifier tubes 2 and 3. A separate rectifier supplies d.-c. power for the motor field.

The phototube is connected in a bridge circuit which is made up of resistors *R*1, *R*2, *R*3 and the phototube. The resistance of the phototube varies as a function of the amount of light which it receives. Therefore, the circuit is adjusted so that when the spot of light is half on the white paper of the template and half on the black line, the signal applied to the left grid of tube 2, is equal to the signal applied to the right grid of this tube. In other words, the voltages across *R*1 and *R*2 are equal.

Under these conditions the output of both plates of tube 2 will be equal. Therefore, the signals applied to the grids of tube 3 will be equal.

Since an equal signal appears on each grid of tube 3,

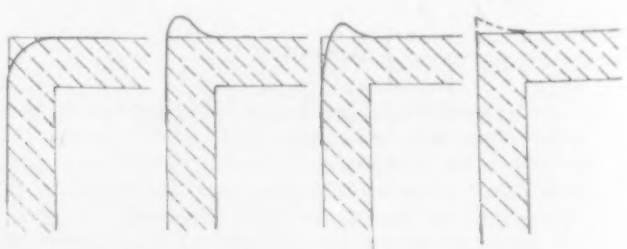

Fig. 10 Fig. 11 Fig. 12 Fig. 13

Fig. 10—Type of Error Produced at Low Speed. Fig. 11—Type of Error Produced at High Speed. Fig. 12—Type of Error Produced at Intermediate Speed. Fig. 13—Change in Template Which May Be Used to Correct Error Produced at Low Speed

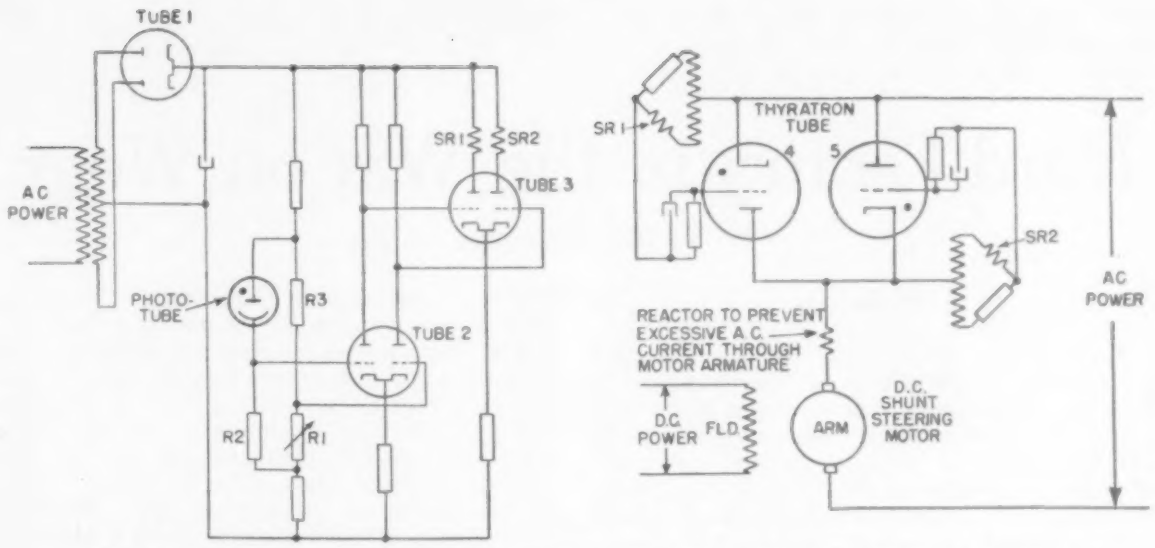

Fig. 14—Electronic Circuit Diagram—Electronic Control for Gas-Cutting Machine

the currents which flow in the windings of saturable reactors *SR*1 and *SR*2, which are connected in the plate circuit of tube 3, will be equal.

The a.-c. windings of saturable reactors *SR*1 and *SR*2, are connected in the grid circuits of tubes 4 and 5, respectively. These tubes are thyratrons which are connected in inverse parallel, so that when tube 4 is allowed to conduct current, the current flows from the a.-c. line up through the motor armature circuit and back into the top a.-c. line. If tube 5 only is allowed to conduct, the current flows in the opposite direction and therefore, flows downward through the motor armature. In that way, d. c. may be obtained from the a.-c. line and the motor may be driven in either direction by turning on either tube 4 or 5.

If both tubes 4 and 5 are turned on by the same amount, the current through the armature of the motor will be a. c. and the motor will not rotate. If tube 4 is allowed to pass slightly more current than tube 5, the result will be a slight "d.-c. component" of current in the armature circuit. Therefore, the motor would revolve slowly in one direction.

The amount of current which is allowed to pass by the thyratron tube is a function of the d.-c. current in the windings of saturable reactors *SR*1 and *SR*2. When the current in the d.-c. winding of *SR*1 (which is in the plate circuit of tube 3) is increased, the amount of current which tube 4 is allowed to pass is increased by phase shifting of the thyratron. If the d.-c. current through *SR*1 and *SR*2 is the same, then thyratron tubes 4 and 5 will both conduct the same amount of current and the steering motor will not rotate.

The net result is that if the voltage across *R*1 is equal to the voltage across *R*2 (that is, the spot is centered on the edge of the line), then thyratron 4 will conduct the same amount of current that thyratron 5 conducts. Under these conditions the motor will not rotate and the control will continue to follow along the line in the same direction.

If the spot should tend to move toward the white paper, the resistance of the phototube will tend to decrease. This will increase the voltage across resistor *R*2 and consequently will cause *SR*2 to pass more d.-c. current, and tube 5 to pass more current through the motor armature. This will result in rotating the steering motor in such a direction that the spot returns to the position where it is centered on the edge of the line.

The action of this control is such that it provides a smooth signal which produces only as much correction as is required. That is, if the spot is only slightly away from its correct position, the amount of torque which is delivered by the steering motor is small and therefore, the spot moves smoothly to its correct position. If, on the other hand a corner is reached and the amount of light on the phototube suddenly becomes considerably greater than it should be (see Fig. 9 (*c*)), then full voltage will be applied to the correcting motor and the steering spindle will be rapidly rotated until the correct position is reached.

Current Welding Literature

Accident Prevention. Needless Welding Accidents. Sheet Metal Worker, vol. 34, no. 9 (Sept. 1943), pp. 30–31.

Aeronautical Instruments. Soldering Electrical Aircraft Instruments, J. J. Schiller. Instruments, vol. 16, no. 8 (Aug. 1943), pp. 491–494.

Airplane Manufacture. Applications of Flash Welding in Aircraft Production, R. Milmoe. Automotive & Aviation Industries, vol. 89, no. 10 (Nov. 15, 1943), pp. 30–32, 88, 90.

Aluminum. Fusion Welding Processes. Aircraft Production, vol. 5, no. 60 (Oct. 1943), pp. 491–494.

Brazing, Aluminum Alloys. Deformation Under Pressure of Brazed Aluminum Tank, L. W. Combs. Product Eng., vol. 14, no. 9 (Sept. 1943), pp. 581–582.

Brazing Pipes and Fittings with City Gas, G. E. Healy and D. M. Johnston. Gas Age, vol. 92, no. 10 (Nov. 14, 1943), pp. 25–26.

Brazing, Possibilities of Furnace Brazing in Aircraft Production, H. D. Samuel, Jr. Automotive & Aviation Industries, vol. 89, no 6 (Sept. 15, 1943), pp. 28–29, 64.

Cutting Tools. Carbide Tools Tipped by Induction Brazing, P. Miller. Am Mach., vol. 87, no. 21 (Oct. 14, 1943), pp. 106–107.

Cutting Tools, Reclamation. New Tools from Scrap High Speed Steel, U. F. T. Norris. Instn. Production Engrs.—J., vol. 22, no. 8 (Aug. 1943), pp. 265–272, (discussion), 273–279.

Cutting Tools, Reclamation. Tool Reclamation Pays its Way, W. A. Johnson and L. Schultz. Am. Mach., vol. 87, no., 22 (Oct. 28, 1943), pp. 83–85.

Cutting Tolls. Latest Methods of Using Arc Welding to Produce High-Speed Cutting Tools, J. A. Neumann. Steel, vol. 113, no. 15 (Oct. 11, 1943), pp. 249, 252, 281.

(*Continued on page 29*)

Hard-Facing in the War on Wear*

By John A. Gallaher†

Abstract

WAR requirements have given an added impetus to the "War on Wear" campaign. Since reduction of excessive wear is the main problem in such a campaign, an analysis is made of the factors causing wear. A chart is presented to show graphically the properties of the various hard-facing alloys and to indicate the kind of wear that each type of alloy can best combat.

The author then discusses selection of the hard-facing material, selection of the base material, preparation of the part for hard-facing and application of the hard-facing material. The numerous factors which enter into the successful solution of each of these problems are enumerated and discussed with examples of actual hard-facing problems that have been successfully solved. The "what-not-to-do" and "why" on some of these problems is discussed.

Hard-Facing in the War on Wear

When in reports from the War Production Board we read that astronomical numbers of combat machines and parts are being produced by the industrial world, we must pay tribute to the men of production. These numbers are an important sign of our ultimate victory. But to the men who are responsible for the maintenance and repair of installations and machinery, such production figures sound the alarm bell.

Evidence of the staggering need for replacement of wearing parts confronts us every day. Operation of equipment twenty-four hours a day, seven days a week, further necessitates the replacement of operating parts more frequently each day or month. Therefore, a continued "war on wear" is necessary in order to reduce the down time and to maintain maximum production.

Most certainly the welding industry has contributed materially to this "war on wear" by hard-facing worn parts; this not only eliminates the need for a new part —which, in these times, is hard to obtain—but also increases the life of the original part. This preventive maintenance is sound practice for new parts as well as for worn parts, so the examples we shall show later will include both types of applications.

Before undertaking any wear problem, we should analyze the job completely. The factors that cause the wear will determine whether the part should be hard-faced or not and what type of hard-facing to use. Since it is generally admitted that very little is known about the mechanism of wear, we can appreciate how difficult it is to measure or predict the wear resistance of a metal. The mechanism of wear involves such a large number of interdependent factors that single, isolated tests can rarely approximate the service conditions.

Our approach to wear problems should therefore be based on actual experience rather than on unpredictable factors.

The accompanying chart (Table 1) is not presented as a hard-and-fast set of rules; its main purpose is to assist in a review of a few types of hard-facing materials to illustrate what can be done to guide in the selection or elimination of certain types of hard-facing materials.

Selection of Hard-Facing Material

The first step in approaching the problem of hard-facing a part, then, is a review of the service to which the part is subjected. Some of the factors to be taken

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Table 1—Guide to Selection of Hard-Facing Materials

Type	Hard Facing Material	Characteristics of Hard-Facing Materials: Resistance to: Abrasion	Erosion	Corrosion	Heat	Impact	Thermal Shock	Applied by	Hardness (as Deposited)	Tensile Strength, Psi.	Special Properties
1	High-hardness cobalt - chromium-tungsten alloy	S	S	S	G	—	—	O-A Arc	54 Rockwell C 45 Rockwell C	47,000	Wear resistance
2	High-tensile cobalt-chromium-tungsten alloy	G	S	S	S	S	G	O-A Arc	31–40 Rockwell C 31 Rockwell C	105,000	Resistance to wear, heat, erosion, and shock
3	High - Chromium Iron Alloy	G	G	—	—	S	—	Arc	40–45* Rockwell C 26–30 Rockwell C	40,000	For manganese steel parts
4	Rods with tungsten carbide grains in a steel matrix	S	—	—	—	—	—	O-A	.....	.....	For earth-moving and agricultural equipment
5	Nickel-base alloy (with Cr, Mo, W, Fe)	—	G	S	S	S	S	Arc	200 Brinell	72,000 to 80,000	Resistance to thermal shock and heat; machinability

S = superior; G = good; — = not outstanding; * = after work hardening.

into consideration in determining the hard-facing alloy to use on the application are:

1. Is the part subjected to abrasion?
2. Is the part subjected to erosion?
3. Is the part subjected to corrosion? If so, from what acid or corrosive material?
4. Is the part subjected to heat? If so, approximately what temperature?
5. Is the part subjected to impact? To what degree?
6. Is the part subjected to thermal shock?

This analysis will frequently show that more than one factor must be taken into consideration. This necessitates checking the available hard-facing materials to determine which would be most suitable to handle this combination of factors. For example, one type of hard-facing material may have superior abrasion resistance but will not withstand severe impact; another may have a good abrasion resistance but will not withstand corrosion; still another type of hard-facing material may withstand all the conditions and yet not withstand thermal shock.

How these factors affect the selection of hard-facing alloy in specific examples will be shown later.

Applying the Hard-Facing Material

The following are to be considered in determining the welding procedure:

1. What is the analysis of the base material?
2. Is it necessary to heat treat the base material before or after hard-facing?
3. How should the surface be prepared?
4. What welding process should be used for the application?
5. Would a casting or strip of hard metal brazed to the part be more economical than hard-facing?

Certain types of hard-facing materials can be applied only by the oxyacetylene method, others only with the electric arc or atomic hydrogen. Still others work readily with any one of the three methods. Some hard-facing materials when applied by the electric arc will crack or have a porous structure. On many jobs surface imperfections are not permissible and one of the other methods of application must be used.

Selection of Base Material

When there is a choice of the base material, consideration should be given to the service to which it is subjected. For instance, if a part is subjected to impact and heat, a base material of high strength must be used. On hot-punching work, where considerable impact is involved, it is possible to make the punch of S.A.E. 1020 providing thicknesses being punched are no greater than $^1/_4$ inch. For punching material several inches thick, however, high-strength base material must be used for the punch body.

Preparation of Part for Application of Hard-Facing Material

The factors to be taken into consideration in the preparation of a part for hard-facing are as follows:

1. Should the part be preheated to prevent cracking or help control warpage?
2. Has sufficient allowance been made to compensate for distortion and shrinkage?
3. Has the part been properly cleaned?

For example, one problem was to apply hard-facing to a 5-in. diam. sleeve having a wall thickness of $^1/_2$ in. so as to end up with a deposit 0.100 in. thick and still retain the 5 in. O.D. Ordinarily one would think the sleeve blank should be prepared by machining it to 4.800 in. O.D. to allow 0.100 in. on each side for the hard-facing deposit. Instead, the sleeve is machined to 4.880 in. O.D. (0.080 in. larger than would seem correct) and a deposit of hard-facing alloy about $^1/_8$ to $^3/_{16}$ in. is then applied on the surface. While cooling from the hard-facing application, the part shrinks so that when ground to a 5 in. O.D. the deposit will be found to be just about 0.100 in. thick—the oversize allowance being absorbed by shrinkage. The hole, which will have become smaller, can, of course, be bored to correct size.

Another example is facing the cutting edge of a long blade. If the blade were laid flat and hard-faced it would distort by bowing during the hard-facing operation. In an attempt to straighten this blade the hard-facing deposit would be put under tension and cracking would undoubtedly result. On the other hand, if a reverse bend is put in the part by clamping the ends of the blade to a table with a support under the center of the blade, it is relatively easy to straighten the part without cracking the hard-facing. As it cools, it will pull itself almost straight, and final mechanical straightening will put the deposit under compression rather than tension.

On large parts and parts having a deposit in the form of a ring, it is often necessary to preheat to prevent cracking. For instance, when a large steam valve disk is hard-faced, uniform preheating of the entire disk reduces the welding time and prevents cracking of the hard-faced deposit.

Advantages of Hard-Facing

The advantages of hard-facing are:

1. Longer life of equipment.
2. Fewer replacements with resultant savings in labor charges and lost production time.
3. Utilization of low-alloy metal as the base for wearing parts.
4. Salvaging or reclaiming of worn parts.
5. Savings in power consumption.
6. General increase in operating efficiency.

The hard-faced part, especially if it is a part with cutting edges, remains sharp longer, thereby reducing the power consumption of equipment—which is a material saving. Hard-facing also increases production and saves time by reducing the number of shutdowns of equipment. For instance, when a hard-faced part lasts four times longer than the original part, three shutdowns are eliminated. In some cases the hard-faced part makes possible a speed-up of equipment and thus contributes in another way to increased production.

An outstanding feature of this method is that the parts can be repeatedly hard-faced. In one drop-forge plant in the Chicago area the same hot-flash trimming die has been maintained in operation by resurfacing for over eight years. While the cost of initial application and grinding in many cases approximates the cost of a new part, the additional life obtained makes the ultimate cost substantially lower.

Hard-Facing of Worn Parts

To illustrate the use of the chart as a guide let us consider a few examples:

Coal undercutter bits are subjected to severe abrasion. They must resist tremendous wear. Two materials on the chart (Table 1) might do, No. 1 or No. 4. Both

Fig. 1 Fig. 2

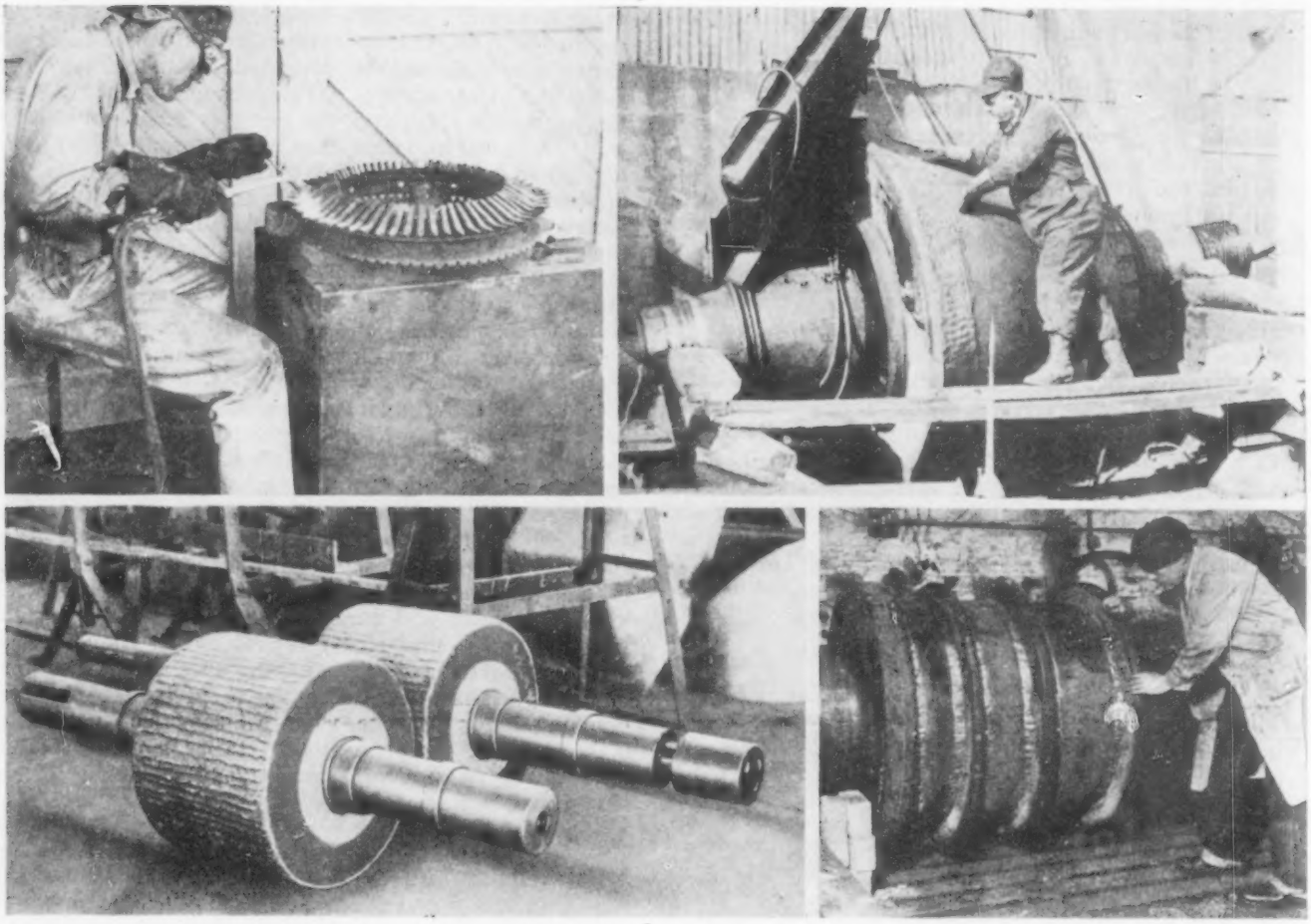

Fig. 3 Fig. 4

Fig. 1—A Rotary Jig Is Used to Expedite Hard-Facing of Coal Undercutter Bits
Fig. 2—Checking the Progress of Hard-Facing on a Manganese Steel Crusher Mantle
Fig. 3—Steel Sand-Crusher Rolls Protected with Type No. 1 Rod
Fig. 4—When This Cogging Mill Roll Was Cleaned Up, Undercutting Revealed That the Alloy Deposit Was Too Shallow

have been tried; both are suitable in certain formations. The No. 4 alloy is the more wear-resistant and is by far the more widely used.

The bits are placed on a rotary jig (Fig. 1) and are tipped with just a drop of the hard-facing alloy. One operator can do from 600 to 700 bits an hour. Due to the close positioning of the bits on the jig, the blowpipe flame acts as a preheating flame on the next bit to be faced.

Another example is the selection of rod for hard-facing manganese steel crusher mantles. One mantle had a life of approximately six months; at the end of this time the $2^1/_2$ in. wall thickness was practically worn through. The principal consideration was severe impact upon the face of the mantle, although the abrasion was also quite severe. The base metal in this case, manganese steel, requiring deposits in places up to $1^1/_2$ in. in thickness, made Type No. 3 alloy the most suitable hard-facing alloy.

One of the castings was reclaimed, after being taken out of service, by building up the worn surface with this alloy, using the electric arc process (Fig. 2). Ninety pounds of the alloy was applied in 25 hours. The total cost of rebuilding, including overhead, amounted to slightly more than 25% of the cost of a new mantle. At the end of four months, after crushing 28,000 tons of copper pyrites, this part showed only $^5/_{32}$ in. of wear. Three more mantles have been reclaimed and all have shown that their life expectancy is twice that of the unfaced mantles.

In similar service, steel sand-crusher rolls (Fig. 3) have been hard-faced with an alloy of Type No. 1. Of course, the principal wear factor is abrasion. Because these rolls are crushing sand, impact is of little consideration. Type No. 1 rod was applied by the electric arc process, and kept the rolls in service for over a year.

Hard-Facing for Resistance to Heat

We are all interested in the techniques used by some of our Allies to reduce down time and save metal. The following is a description, sent from England, of a cogging roll used in a steel mill there.

"In hard-facing a pair of cogging mill rolls, one of which is shown in the illustration (Fig. 4), the groove for the alloy deposit was designed as shown in Fig. 5. The illustration shows the details of this groove and also the number of beads required. This number will vary with the skill of the operators but the seven shown are probably the minimum.

"Rolls were made from steel with 0.35 to 0.45 carbon and 1.0 to 1.5 nickel. They were preheated to 200° F.,

and hard-facing was carried out with 1/4-in. diam. (Type No. 2) coated rod, using approximately 200-amp. direct current with the polarity reversed. The deposit was laid down in the groove by working the arc from a semivertical position, since it was found that this position produced a smoother deposit and one that was more free from cracking. For hard-facing the flanges the roll was stood on end (Fig. 6).

"The deposits were machined with tungsten carbide tools; rough machining was done at one revolution in 80 sec., finishing at one revolution in 40 sec. The diameter of the rolls at the base of the flange was 36 in."

"When the last report was made available, these rolls had made four runs rolling a total of 147,000 tons. They are still in service and will last some time yet. This record is contrasted to the life of standard alloy steel cogging rolls of approximately 90,000 tons."

Hot-trimming dies are used for trimming the flash from ring gears and many other forgings of both plain

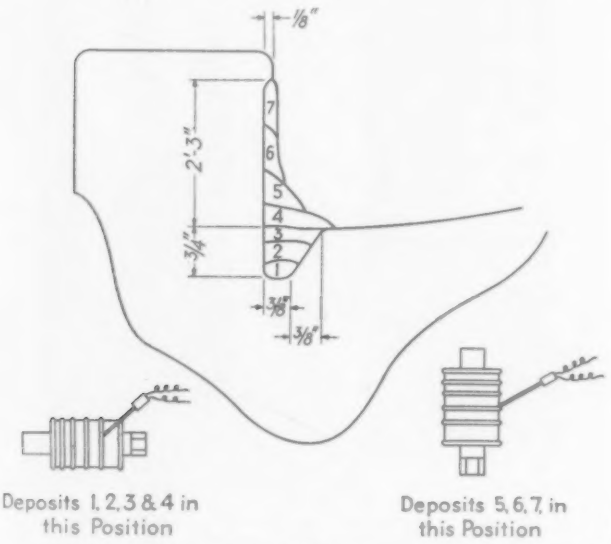

Fig. 5—The Groove for the Alloy Deposit Was Redesigned to Combat the Undercutting Found in the Roll (Fig. 4)

and alloy steel. Since most of the dies can be hard-faced with an alloy of Type No. 2, this type has been most widely used. The die shown here, (Fig. 7) which is for hot-trimming a ring gear forging, was originally made of a special steel. Its life averaged approximately 2000 pieces. Since an alloy of Type No. 2 has been applied to a 3140 S.A.E. steel base, 43,000 pieces is not unusual.

More recently an alloy of Type No. 5 has been used for hard-facing hot-work punches and dies, especially when the operation involves thermal shock. Type 5 alloy can be machined, can be applied with the electric arc and requires no heat treatment. One punch on which this metal has been applied is used for piercing a 1 3/4-in. diam. hole, 4 1/2-in. long, in nitralloy steel bushings. Due to the depth of the hole, the punch is water cooled to prevent overheating. It is obvious that the factors to be considered in determining the hard-facing alloy to be used are heat, impact and thermal shock. Because of these conditions an alloy of Type No. 5 was chosen. After it was deposited by the electric arc, the surface was machined to size in 15 min. This hard faced punch (Fig. 8) produced between 3000 and 4000 parts before it had to be resurfaced. Prior to hard-facing, the punches used on this job could pierce only 100 pieces before replacement became necessary.

Figure 9 shows piercing punches used for punching

Fig. 6—The Deposit Was Laid Into the Groove (Fig. 5) from a Semivertical Position

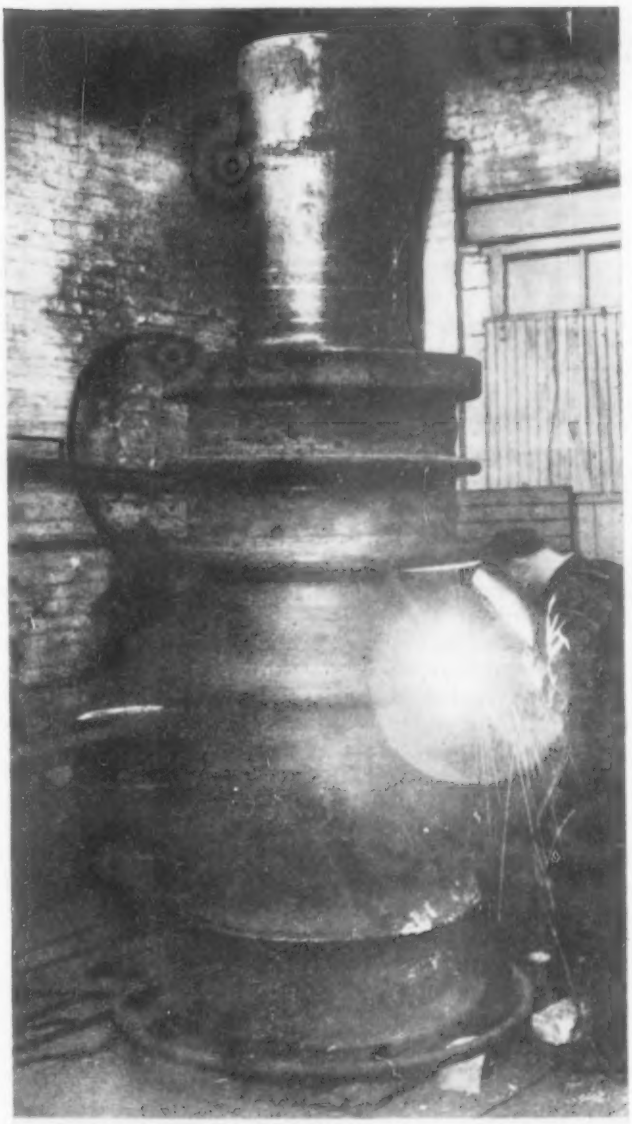

Fig. 7—Hot-Trimming Die Used for Trimming the Flash from Ring-Gear Forgings

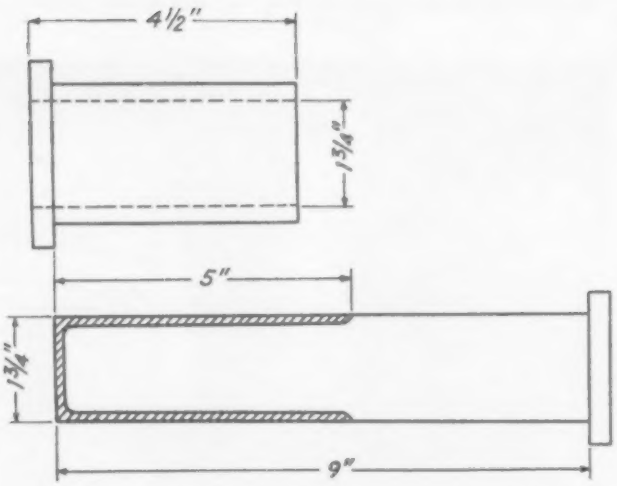

Fig. 8—Detail of a Hard-Faced Punch Used to Pierce Alloy Steel Bushings

75-mm. shells. Scrap punches were used and were machined undersize 1/16 in. on the diameter and nose before hard-facing.

A review of this operation showed that the punch had to withstand heat, impact, and thermal shock. The heat was excessive due to the depth of the hole being pierced and, since the punch was immersed in water after each piercing operation, thermal shock occurred.

A review of the available hard-facing materials showed that there were just two that might withstand this thermal shock—alloys of Types No. 2 and No. 5. When these two were tested, No. 5 was found to be successful. A 5/32-in. rod was applied by the metallic arc process, and the deposit was machined to size with a high-speed steel tool.

The hard-faced punch produced 2000 shells during the operating life of the hard-faced surface. During the run it was buffed every 500 shells to improve the piercing action. The previously used tool steel punch produced 450 shells during its useful operating life, and had to be buffed every 150 shells.

Hard-facing has been reapplied to this part several times since the operation was first tried and the original punch body is still in use.

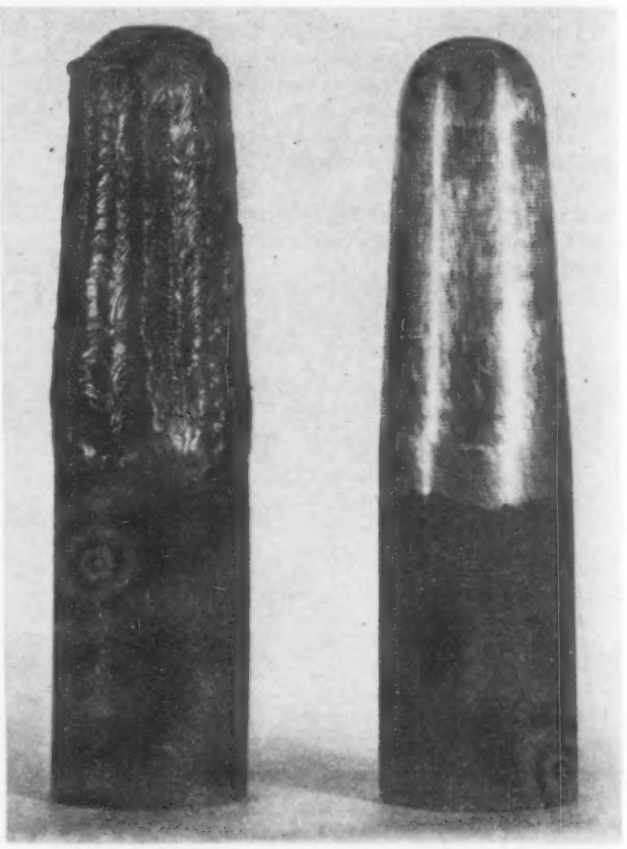

Fig. 9—Punches Used for Piercing 75-Mm. Shells (Left) Hard-Faced (Right) Machined

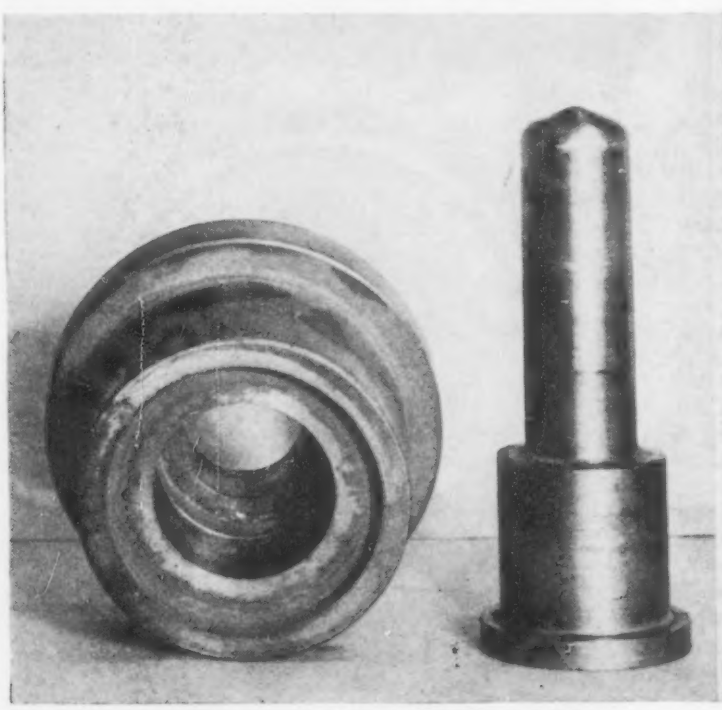

Fig. 10—A Hard-Faced Punch and Die Used for Forging Bomb Booster Caps

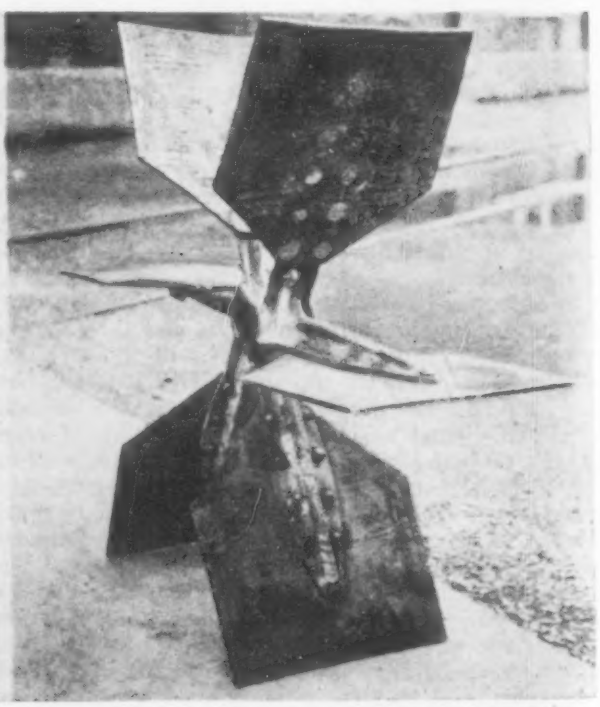

Fig. 11—The Life of This Lime Blower Impeller Used in Sugar Processing Was Increased Almost Tenfold by Careful Hard-Facing

Still another successful application of Type 5 alloy was on a forming and piercing punch and die for forging bomb booster caps.

The alloy deposit (Fig. 10) is made only on those surfaces of the die and punch which are subject to the most extreme abrasion. The rough-deposited alloy surface is machined with a high-speed steel tool.

After punching approximately 6000 caps, the punch and die require a new deposit of alloy. When refacing is necessary, the hard-faced surface is machined off and a new deposit is applied with the electric arc. The cost of fabrication by this method is equal to or slightly less than that of completely new dies. The economy

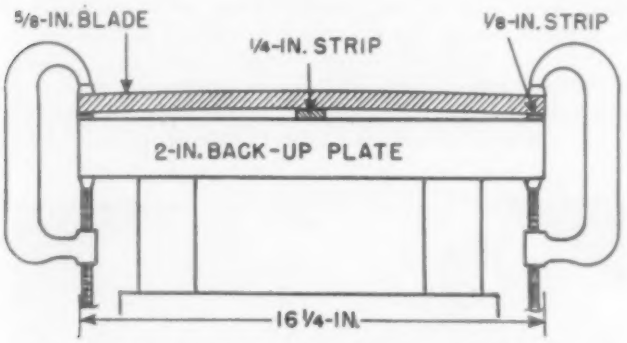

Fig. 12—To Counteract Warpage, Each Blade of the Impeller (Fig. 11) Was Clamped as Indicated During Hard-Facing

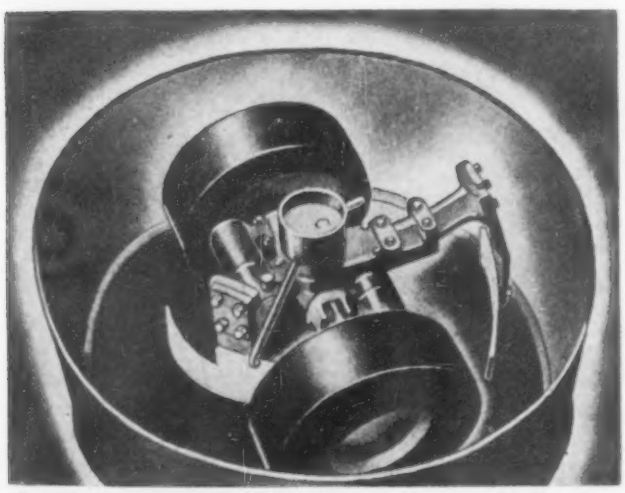

Fig. 13—The Lower Edges of the Blades Receive the Heaviest Wear in This Mixer for "Mulling" Foundry Sand

of the operation is emphasized, however, by the fact that of the 2000 caps that can be punched with steel punches, the last 500 to 800 are marked due to the washing out of the die. With a hard-faced punch and die, all 6000 forgings are good, and the run is stopped before heat checks can cause any marking of the parts.

Referring again to the chart (Table 1), we find that we have shown applications which illustrate how to overcome wear from abrasion, heat, impact and thermal shock. The next illustration shows a part which was subjected to wear from abrasion and corrosion, and it emphasizes also the necessity of analyzing the conditions of a hard-facing application before going ahead on a hard-facing job.

Figure 11 shows a lime-blower impeller used in sugar processing. It was important that these blades, $16\frac{1}{4}$ in. wide, should be flat and that the blower should be well balanced when the hard-faced blades were assembled to the spider.

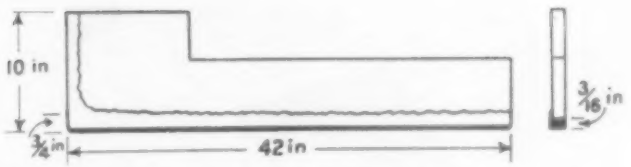

Fig. 14—The Blades (Fig. 13) Were Successfully Hard-Faced by Using This Setup

To counteract warpage, each blade (Fig. 12) was clamped to a back-up plate with spacer bars inserted as shown, to give a reverse bend. When completed and the clamps removed, the blade sprang back to less than $\frac{1}{32}$ in. out-of-true. The blower, after assembly, was less than one ounce out of perfect balance, and this was adjusted when hard-facing rod was applied to protect the rivet heads from wear. Type No. 1 rod was used here to combat the severe abrasion and the moderate corrosion. Hard-facing kept this blower in service 316 days as against 34 days, which was the average life of a blade before hard-facing was adopted.

Where a part is not subjected to erosion, corrosion or heat, and does not need to be extremely smooth or take a high polish, greatest wear resistance can be obtained with hard-facing alloys of Type No. 4, which consist of grains of tungsten carbide applied in a matrix of steel. Figure 13 shows a commonly used type of mixer for "mulling" sand in foundries. This consists of two large rollers and two plows or blades which rotate with the rolls, mixing the sand and guiding it under the rollers.

A layer of Type No. 4 rod about $\frac{3}{16}$ in. in thickness was applied to the lower edge of the blades where the wear was heaviest; the front of the blades, which received somewhat less wear, was protected with a coating of Type No. 1 hard-facing alloy $\frac{3}{4}$ in. in width (Fig. 14).

The life of these blades was thus increased from about 3 to about 12 days. They were hard-faced this way again and again. The horsepower required to run the machine was reduced by about one-third because the

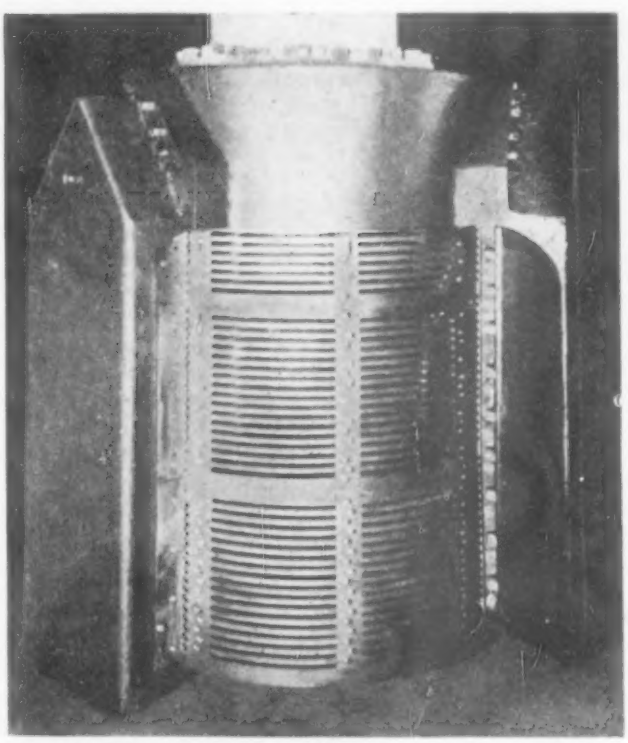

Fig. 15—A Comminutor (Large Rotary Pump and Cutter Device) for Treating Sewage

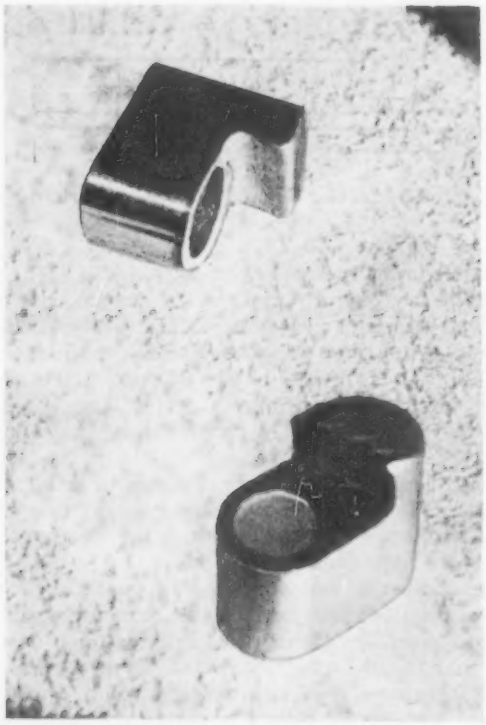

Fig. 16—A Close-Up of Two of the Teeth in the Comminutor Shown in Fig. 15

plows stayed sharp and cut through the sand more easily. This example shows that we are not limited to one material on a part. If the wearing conditions vary on different surfaces, there is no reason why they cannot be hard-faced according to the needs evidenced by an analysis of the job.

Hard-Facing for Resistance to Corrosion

Since corrosion varies from mild to severe according to the chemical or its concentration, selection of the hard-facing alloy to combat a specific corrosive condition can best be made by references to tables of corrosive action on metals which your hard-facing material supplier can furnish you. Most of the alloy hard-facing materials are good for resisting average corrosion, but there are some special conditions which some of them cannot resist, and in case of question the tables of corrosive action should be the guide.

Figure 15 shows a comminutor, a large rotary pump and cutter device for treating sewage. In its operation the sludge passing through the openings is cut into small pieces to facilitate the chemical action which follows in the treating process. Wood, cloth, vegetable matter, rubber and even metal pieces sometimes are encountered, and the teeth and combs must be of sufficient hardness to resist the wear from these materials. The combs for this machine are hard-faced with Type No. 1 hard-facing rod and ground to size. The excellent service results, in comparison with steel combs formerly used, have caused the manufacturer to standardize on hard-faced combs for the machines which he builds.

This is a close-up of two of the teeth in the comminutor. These parts (Fig. 16) pass through the combs and cause the cutting action. Instead of being hard-faced, these teeth are made up by the supplier of hard-facing materials as special small castings. Improved foundry and finishing methods make it possible to precision cast these teeth to close tolerances. This example is typical of how manufacturers are progressing from hard-facing of single parts to the production hard-facing of many identical pieces and the use of wear-resistant hard-facing alloy parts, precision cast to accurate dimensions and installed as a part of the new machine.

Fig. 18—This Hard-Faced Valve Is Shown After Operating 714,000 Air Miles

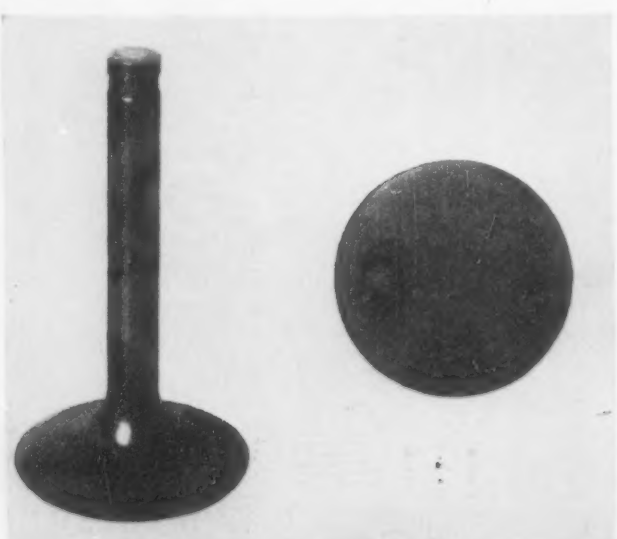

Fig. 17—Hard-Faced Aircraft Valve Which Ran 3819 Hr., Equal to 680,000 Air Miles

Another example involving much more severe corrosion as well as abrasion, heat and impact is the current use of hard-facing on aircraft valves. The valve shown in Fig. 17 ran 3819 hours—the equivalent of 680,000 air miles.

The valve shown in Fig. 18 operated for 714,000 miles. Valve life running into these figures was unknown before hard-facing was introduced. Practically every airplane motor and a great many other types of motors in use today are fitted with hard-faced valves. The conditions met are wear, heat, corrosion and impact; Type No. 2 alloy is perfectly suited for this application.

Speeding-up of the hard-facing application is receiving much attention in these days. One plant adapted a

Fig. 19

Fig. 20

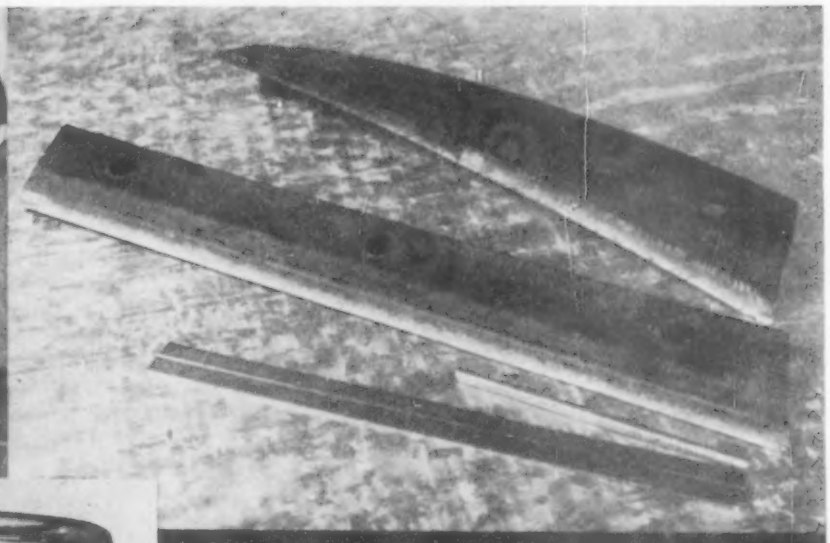

Fig. 21

Fig. 22

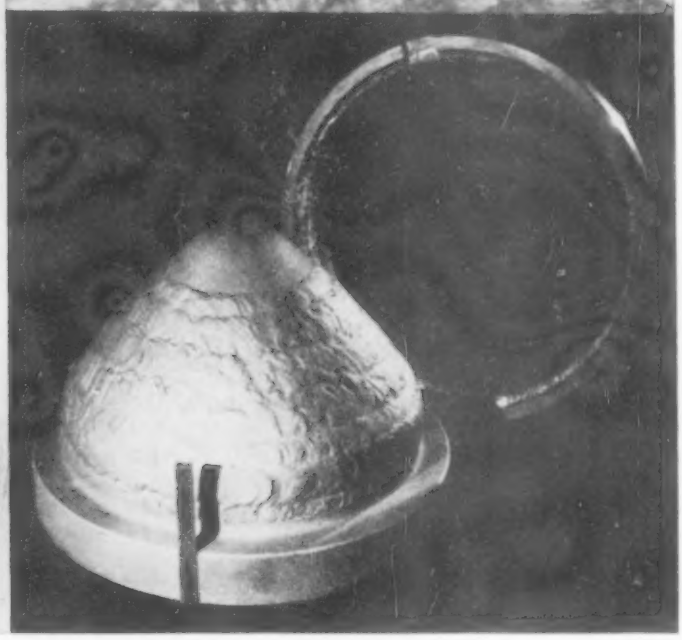

Fig. 19—This Portable Oxyacetylene-Cutting Machine Was Successfully Adapted to Mechanize the Hard-Facing Operation

Fig. 20—The Smoothness of the Deposit Made with the Machine (Fig. 19) Is Readily Seen

Fig. 21—Alloy of Type No. 2 Successfully Protected the Seat and Disk of This Globe Valve

Fig. 22—This Hard-Faced Parabolic Disk and Seat on a Flow-Control Valve Handles 350,000 Lb. of Steam Per Hour, at 750 Deg. F. and 400 psi.

portable oxyacetylene cutting machine to mechanize and speed up the application of the hard-facing metal to knives for ensilage cutters (Fig. 19). The blowpipe travels along the blade, which is held in a jig, and the operator feeds the hard-facing rod into the flame by hand. A foot switch stops and starts the machine.

The smoothness of the Type No. 1 alloy deposit can readily be seen in (Fig. 20), which shows the deposit made by the semiautomatic setup, before grinding. Hard-faced blades last six weeks without sharpening whereas carbon steel knives need sharpening every eight hours.

Hard-Facing for Resistance to Erosion

An analysis of the service conditions of valves for steam plant service gives these requirements for hard-facing material:

It must:

1. Be hard—and also abrasion and erosion resistant even at red heat.
2. Take a high polish and have a low coefficient of friction.
3. Resist scoring, galling, seizing and wire drawing.
4. Remain free from corrosion and pitting.

Experience has shown that Type No. 2 alloy is ideal for this service and a couple of examples will show the outstanding service life which this application gives.

The seat and disk of this 5-in. 900-lb. globe valve (Fig. 21) were hard-faced with alloy of Type No. 2. This valve and others in one station operating at 650 psi steam pressure and 850° F. have given five full years—23,570 hours—of service without any repairs being necessary.

A parabolic disk and seat on a 16-in. flow-control

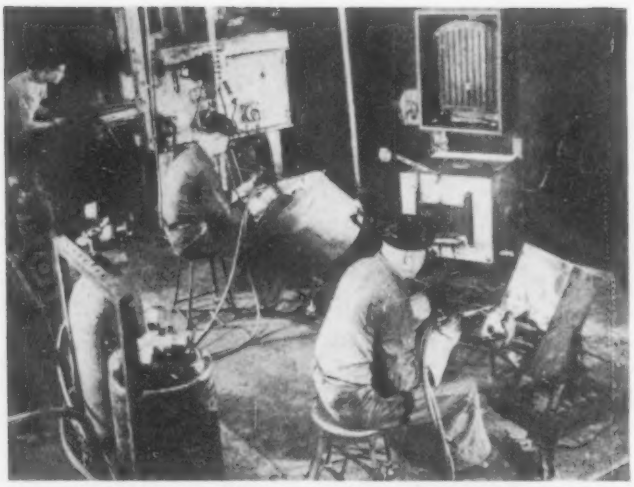

Fig. 23—A Rotating Unit or Jig Saves Time in Hard-Facing Valve Parts

valve (Fig. 22) were hard-faced with Type No. 2 alloy. The maker of this valve applied this particular alloy since he knew that this was a satisfactory way of assuring long life in a service which involved the handling of 350,000 lb. of steam per hour at a temperature of 750° F. and a pressure of 400 psi.

Large production requirements have made it desirable to mechanize some phases of the application. This (Fig. 23) shows a rotating unit or jig on which the valve part is placed after being taken from the preheating furnace.

The use of the rotating unit speeds up the application, and machining the surface of the valve instead of grinding makes further savings in time. A tungsten carbide tool is used in this machining operation (Fig. 24) at a surface speed of 25 to 40 surface feet per minute.

Manufacturing of uniform hard-faced parts in large quantities has brought about the need of reducing the cost of the hard-surfacing operation. Figure 25 shows a single-spindle automatic hard-facing machine for applying hard-facing metal to the surface of high-temperature high-pressure steam gate valve seats. The machine can accommodate parts with diameters from 6 to 24 in. It produces a deposit $1^1/_4$ in. wide, $^1/_8$ in. thick, at the rate of 1 in. per minute per inch of diameter; that is, a 6-in. ring every 6 min. or an 18-in. ring every 18 min. Two preheating blowpipes make special preheating furnaces unnecessary. Type No. 2 hard-facing rod is fed automatically. The only manual operation is the loading and unloading of the rings. The smooth-surfaced deposit is free from any defect. The use of this machine has resulted in savings of 30% in metal deposited and 20% in machining time for finishing the surfaces.

Other automatic hard-facing machines are being developed where production is high enough to warrant their application. Not only do they effect savings in material and time but they eliminate the fatigue factor for the operator and produce uniform high-quality parts.

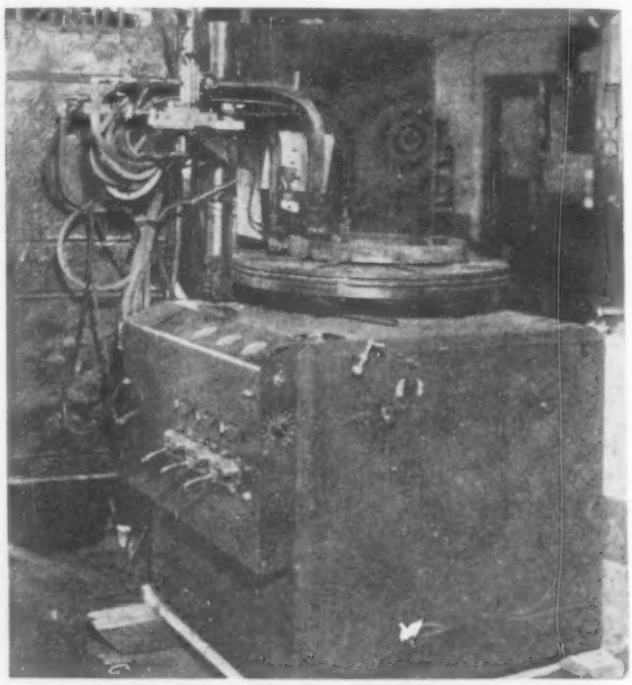

Fig. 25—Costs for Hard-Facing Gate Valve Seats in Large Quantities Are Reduced by Using This Single-Spindle Automatic Hard-Facing Machine

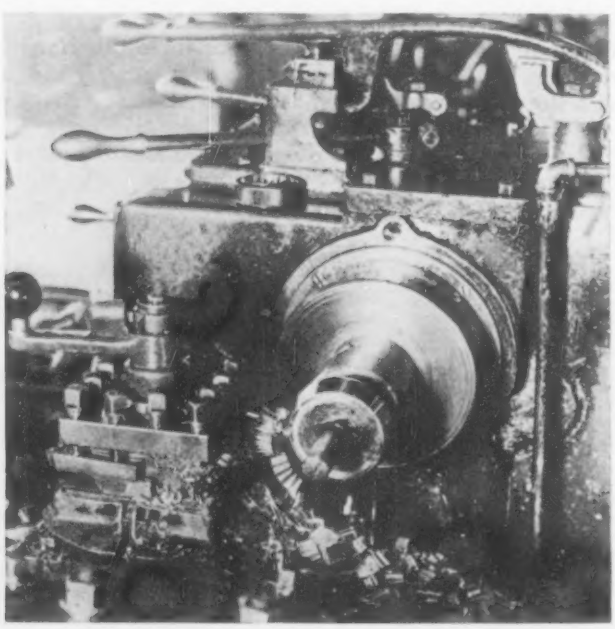

Fig. 24—Machining of the Valve-Seating Surface (Fig. 23) Is Faster Than Grinding

Two Recommendations for Future Action

These examples and the table will show the need for two general campaigns which should be followed in our war against wear:

First, *analyze the hard-facing problem*. Select the correct hard-facing alloy to combat the severity and nature of the service conditions. Prepare the part properly. Allow for shrinkage, distortion, expansion and similar factors. Use the best welding procedure. Machine or grind to meet service requirements.

Second, *give a thought to future hard-facing*. Review your shop operations, machines, equipment, implements, tools—even scrap pile—to be sure that you are salvaging every useful part that can be restored by hard-facing. Consider the possibility of standardizing on hard-faced parts in your product where wear is most severe. Look, also, to the possibility of using jigs or furnaces to speed up the application. See whether there are some parts of your equipment which might last longer if made from a casting of hard-facing alloy.

These tactics and strategy will help win your "war on wear." Knowing how to carry out each move of procedure in the battle, what weapons or hard-facing materials to employ is the mark of a skilled industrial commander.

Carbon Arc Welding of Naval Brass*

By K. L. Walker†

FUSION, or autogenous, welding is produced by either the carbon arc or metallic electrode methods. Electric welding using carbon arc is the older of the two welding processes and was originated by Benardos over 55 years ago. With this process, as the name implies, graphite carbon electrodes are used; these are of various sizes and tapered to a point to focus the heat and prevent the arc from wandering. The length of taper of the electrode is 4 to 5 times the diameter of the carbon, which in turn varies in thickness according to the class of work being done. The carbon is mounted in a suitable holder, as close to the taper as the work will allow and an arc of medium length, $^1/_4$ to $^3/_8$ in., is held using straight polarity or electrode negative, the positive being attached to the work. It is important to observe that this polarity is established correctly, for besides being difficult to maintain a stable arc, should reversed polarity be used, molecules of carbon would be conveyed from the electrode to the work. The carbon would be absorbed in the newly deposited metal, producing a porous weld in non-ferrous material, and rendering steel brittle and difficult to machine.

* Presented at the Annual Meeting, A.W.S., Chicago, Ill., Oct. 18 to 21, 1943.
† Foster Wheeler Corp., Carteret, N. J.

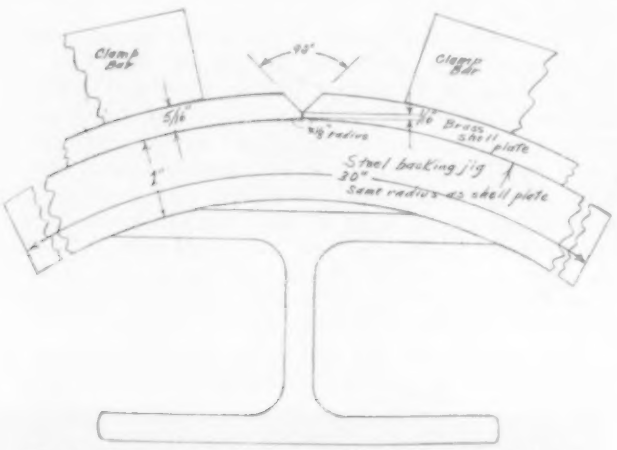

Fig. 1—Diagrammatic Sketch of Longitudinal Seam Setup

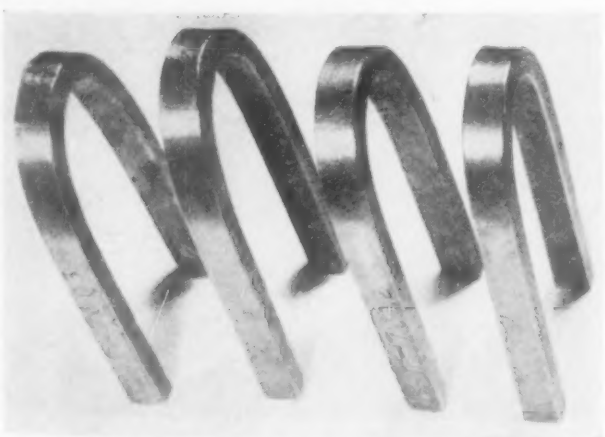

Fig. 2—Face and Root-Bend Specimens of Silicon Bronze and Oxweld 25M Filler Rods on Naval Brass

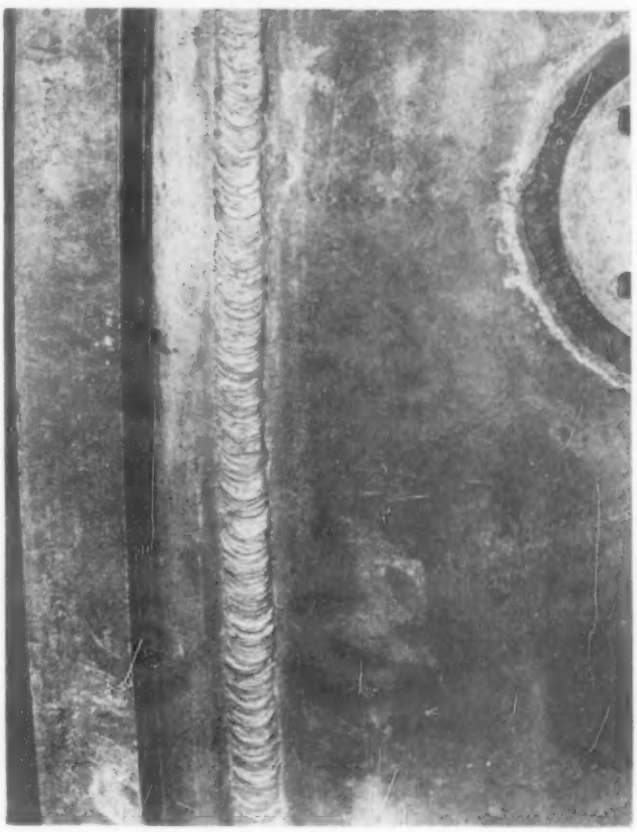

Fig. 3—Outside Girth Seam Weld; Oxweld 25M Filler Rod

The application of carbon arc welding has proved successful with large numbers of low-pressure vessels which previously were fabricated by metallic arc and oxyacetylene welding. The material used in these vessels is a brass alloy which is known in the trade as Naval Brass and has nominal composition limits of copper 59–63%, lead 0.20, tin 0.50–1.50%, iron 0.06 and the remainder zinc. This material, being a hot-rolling alloy, is received in the desired thickness of $^1/_4$- and $^5/_{16}$-in. sheets. Upon receipt at the shop, the edges are planed to a 45° bevel and $^1/_{16}$-in. lip. After this machining, the sheets are annealed in the flat in a car-type furnace at a temperature of 1050° F., using butane gas as a fuel, the furnace temperature being automatically controlled.

Following the annealing operation the flat sheet is formed into a cylinder and is placed on a jig as shown in Fig. 1 for welding the longitudinal seam. During all welding procedure a minimum preheat of 300° F., is maintained in order to equalize welding stresses induced by the rapid quenching of the weld metal and to

Fig. 4—Inside Girth Seam Weld

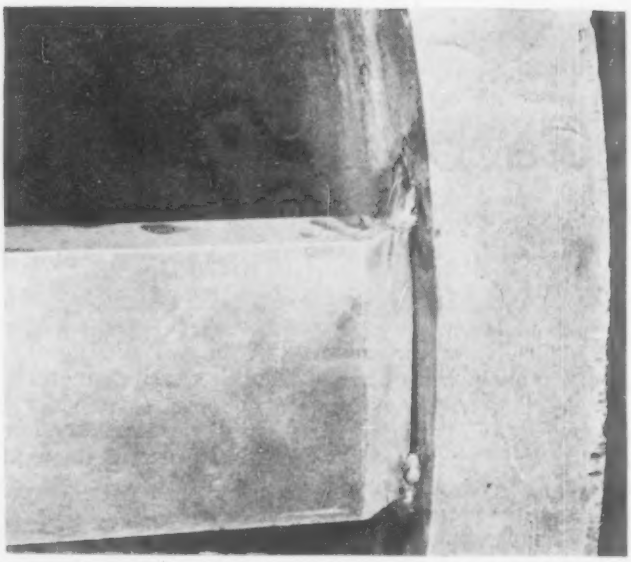

Fig. 7—Strongback to End Flange Joint, Before and After Welding

obviate season cracking. The filler rod used for all downhand seam welding is known in the trade as Oxweld 25M and is of the following approximate composition: copper 66.08%, tin 0.75, silicon 0.07, manganese 0.01, iron 0.95 and the remainder zinc. This is a fluid-flowing rod and is characterized by good physicals, high welding speed and freedom from porosity. Carbon arc welds on Naval Brass have given tensile values of from 50,000 to 56,000 p.s.i. Face and root bend specimens of 25M for seam welding and silicon bronze for fillet welding are shown in Fig. 2.

The first pass in the groove is made with a $^3/_{16}$-in. filler rod and a $^3/_8$-in. carbon using approximately 300 amp. and 25–28 v. Powdered flux is sprinkled ahead of the weld and each layer of weld metal is thoroughly cleaned before the following layer. The number of craters should be kept to a minimum and it is advisable to start succeeding rods about an inch back from the last crater. The second finishing pass is made with a $^1/_4$-in. rod and $^1/_2$-in. carbon using 400–450 amp. and 28–30 v., Fig. 3. The use of proper jigs, and the concentrated heat of the carbon arc, in preventing large areas of parent metal from reaching elevated temperatures, with the attendant higher welding speeds, have practically eliminated distortion. It is customary to weld all seams without any subsequent rerounding operations.

A hot-spun dished head, $^3/_8$ in. in thickness, is welded to one end of the shell, and an integral hub, butt-welding type flange, is welded to the other end. The end flange is fabricated by rolling a $2^1/_2$- x 3-in. bar stock and welding the double-vee butt weld by oxyacetylene followed by the machining of the flange. Head and end flange girth seams are assembled and tacked rigidly and backed up by a jig of steel bar stock which maintains correct fit-up and acts as a chill ring. All seams are grooved and welded inside with one pass of $^1/_4$-in. rod as in Fig. 4. All groove welding is done in a flat position made possible by the use of power rollers.

A strongback for the end flange is fabricated by fillet

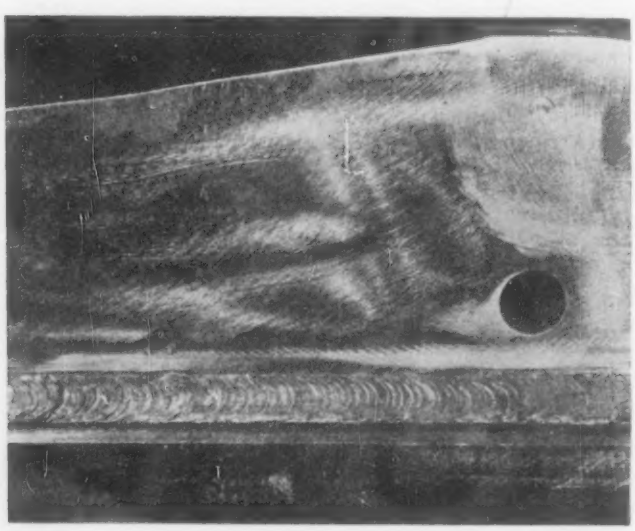

Fig. 5

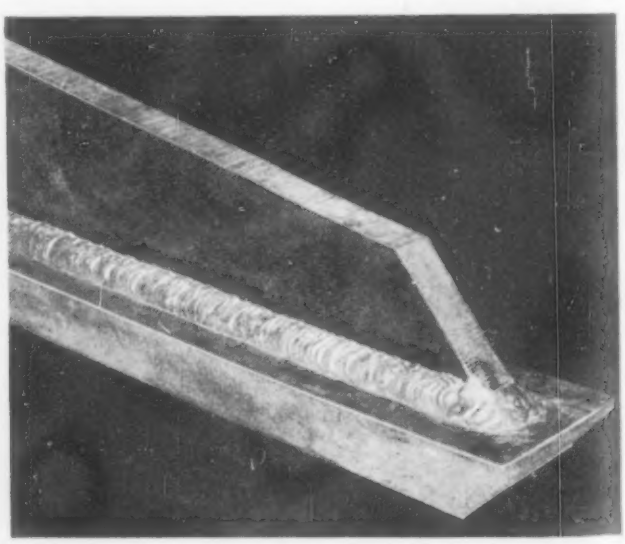

Fig. 6

Figs. 5 and 6—Flange Strongbacks, 1 x 6-In. Tapered Bar to a $1^1/_2$ x 4-In. Bar

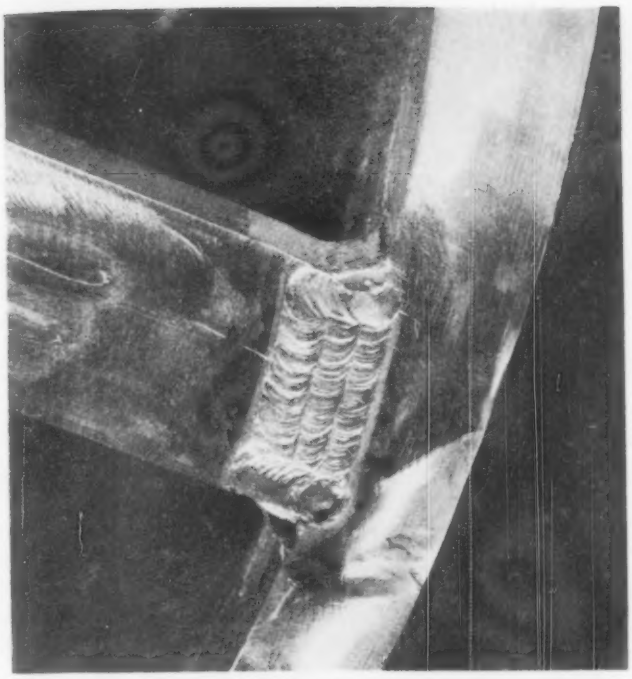

Fig. 8

Fig. 8—Strongback to End Flange Joint, Before and After Welding

welding a 1- x 6-in. bar to a $1^1/_2$- x 4-in. bar with a $^5/_8$-in. fillet as shown in Figs. 5 and 6. This is in turn welded into the end flange with a $1^1/_4$-in. deep bevel as shown by Fig. 7, welding with multiple passes with the shell positioned in a jig so that the welding is completed downhand. The completed joint, Fig. 8, shows the technique of using string beads on these heavier sections. The end flanges are completely faced and drilled after the completion of these joints.

All fillet welds are made with a silicon bronze rod of A.W.S. Group 8W. This type rod is not so fluid under the arc and can be handled readily on all types of fillet welding giving an excellent finish appearance. Fillet sizes are $^3/_8$ and $^1/_2$ in. The fillet welds on the nozzle pads to the shell are positioned at approximately 45° and welded from the 3 and 9 o'clock positions to 12 o'clock. The work is then moved 90° to place the opposite side in position and the layer completed in like manner. This causes the welder to work always slightly vertical, giving good penetration and allowing him to flow each side of the fillet into a proper 45 with a flat weld contour. Figure 9 shows the welding of a pad to the dished head and Fig. 10 that of the weld on one of the nozzle pads to the shell. The first bead is made with a $^5/_{32}$-in. rod and a $^5/_{16}$-in. carbon using approximately 200–250 amp. and 23–25 v. The second layer is made with a $^3/_{16}$-in. rod and a $^3/_8$-in. carbon, using 275–300 amp. and 25–28 v.; it is deposited with a weaving motion. To prevent distortion on the shell, nozzles are jacked out with radius pads and the preheat of 300° is maintained. Figure 11 shows a pad weld on one of the dished heads. Figure 12 is the corner weld on the inside

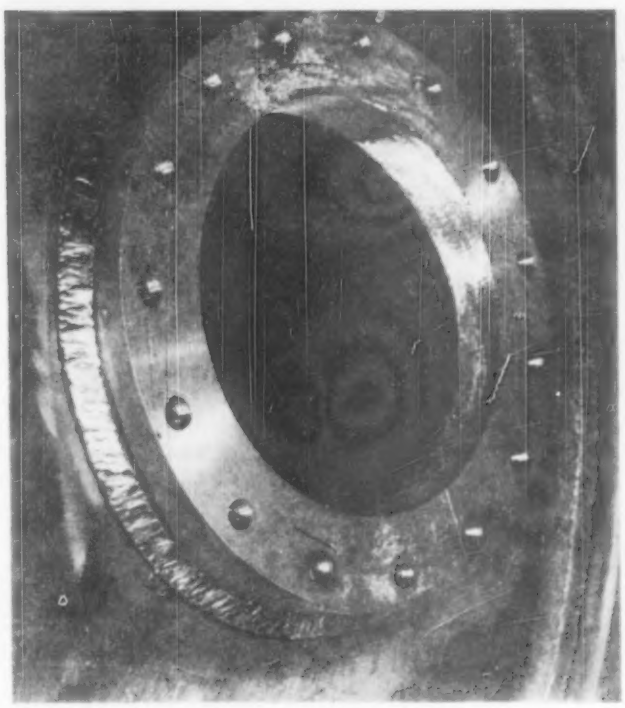

Fig. 10—Pad Weld to Shell

Fig. 9—Carbon-Arc Welding of Nozzle Pad to Dished Head on Positioner

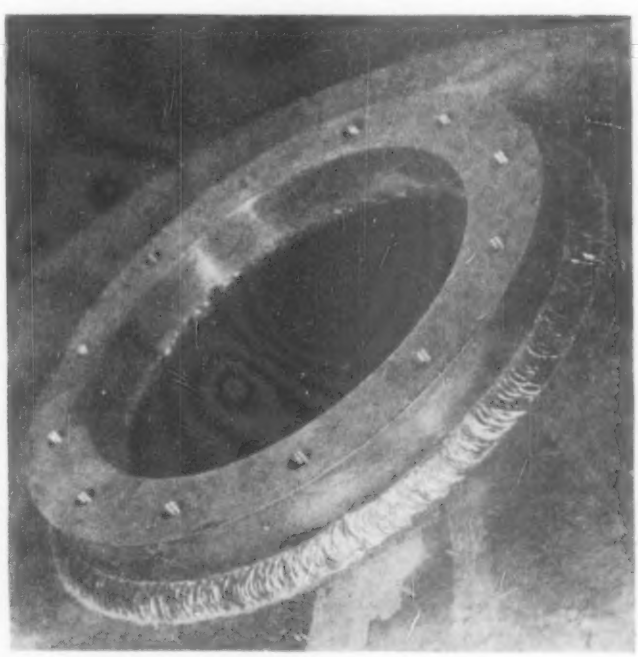

Fig. 11—Pad Weld to Dished Head

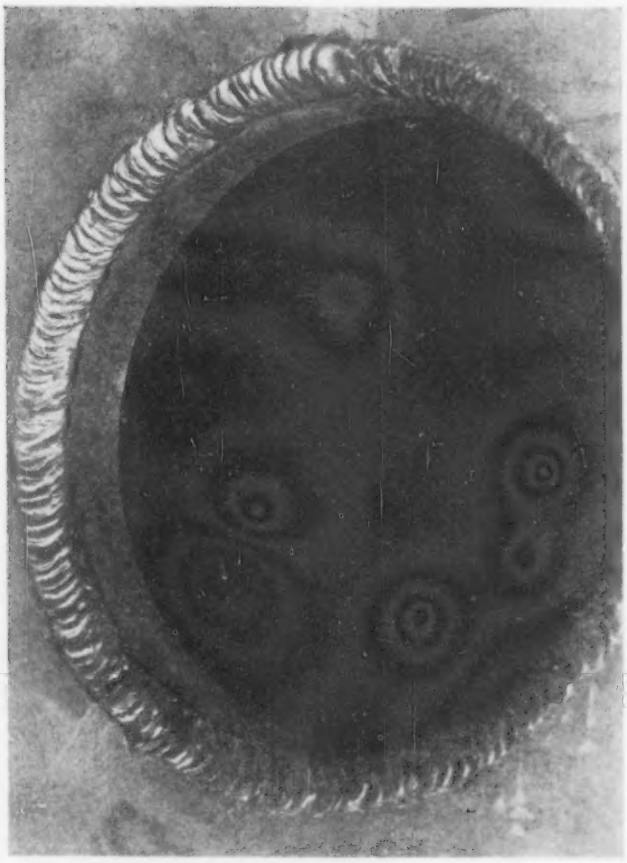

Fig. 12—Inside Corner Weld of Nozzle Pad

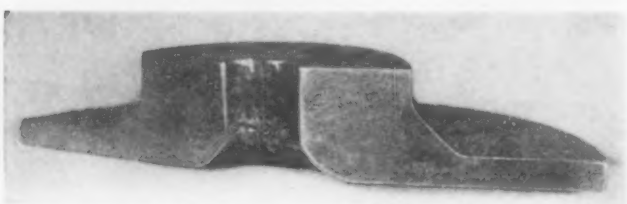

Fig. 13—Cross Section of Pad Weld to Shell; Note Fusion and Lack of Undercutting

Fig. 14—Carbon-Arc Welded Internal Angles and Clips

of a pad and Fig. 13 the cross section of a completed nozzle pad which gives an idea of the results obtainable. All nozzle pads are completely machined before welding to the shell and blind flanges of steel are bolted on to prevent distortion of the face.

Figure 14 shows a view of internal clips and angles welded to the shell. Preheat is again emphasized here for any local tack welds. Steel stiffener rings and saddles are fillet welded to the shell as shown in Fig. 15 and 16. Companion shells for these units are fabricated in the same manner and Fig. 17 shows a typical weld on the slip-on end flange and Fig. 18 that of the nozzle

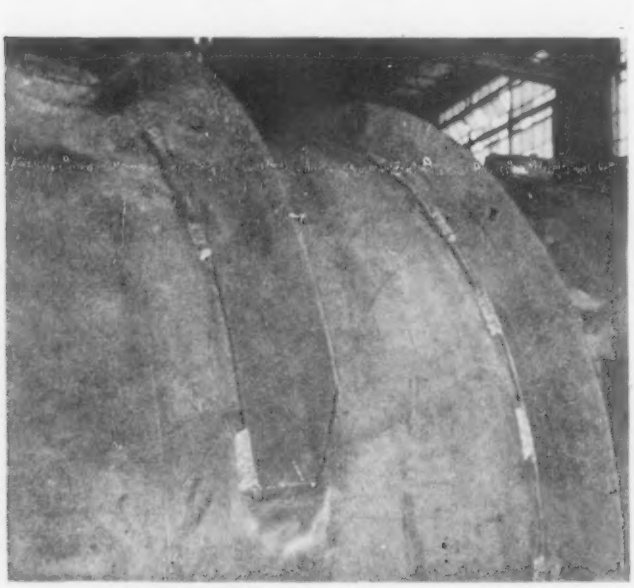

Fig. 15

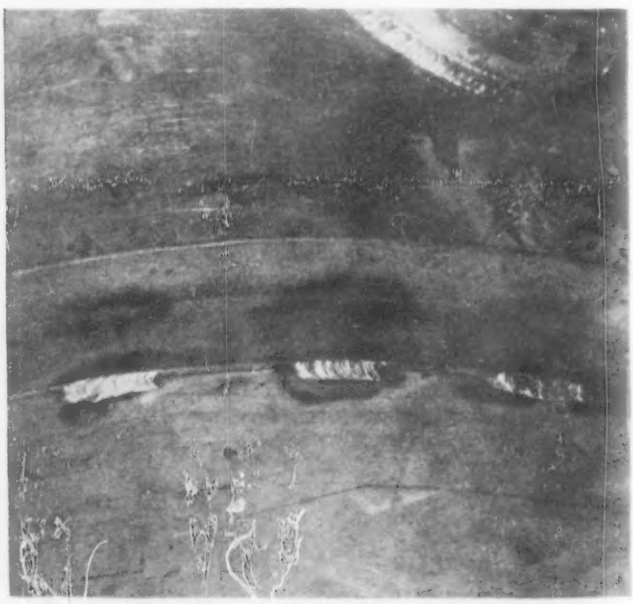

Fig. 16

Figs. 15 and 16—Steel Stiffener Angles Welded to Shell

fabrication on these shells. Ample use is made of power rolls and positioners to place the welds in the best possible position. Finished vessels are stress relieved at 550° F. The complete absence of weld splatter eliminates all cleaning problems.

Proper ventilation should be provided with some means of exhausting the smoke and fumes from the weld to provide good vision and to protect the operator's health. The training time for apprentice welders has been comparable to other processes with women also being trained and qualified for this work.

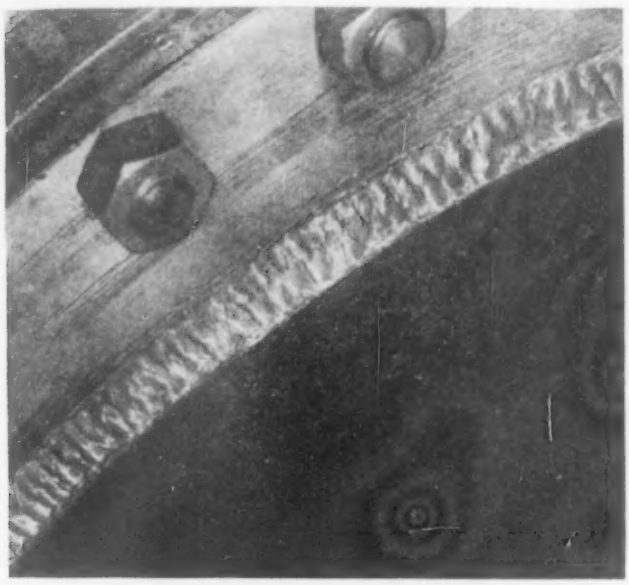

Fig. 17—External Fillet Weld on Slip-on End Flange

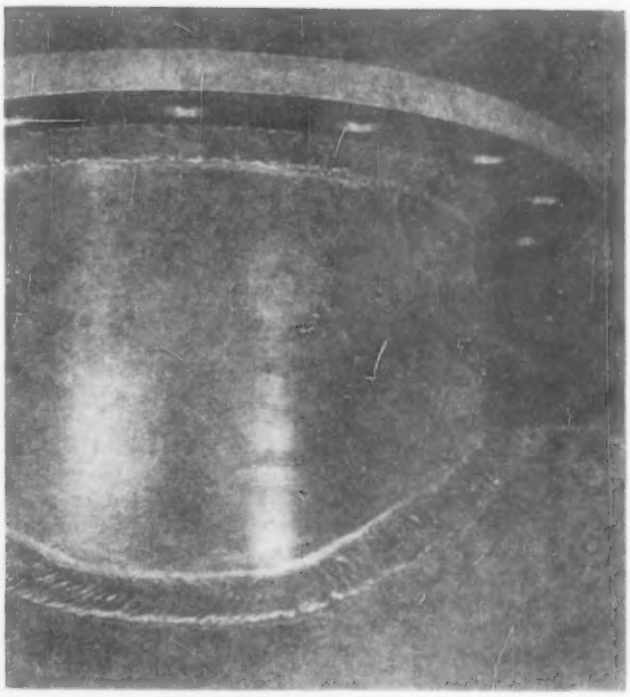

Fig. 18—Nozzle Fabrication

All welds on these units have been free from trouble in service and it can safely be stated that the application of carbon arc welding, with proper procedure and control, has proved itself a very acceptable method of fabricating Naval Brass vessels from the viewpoints of quality, time, cost and appearance.

Current Welding Literature

(*Continued from page 15*)

Electric Arc Welding, E. S. Waddington. Soc. Engrs.—J. & Trans., vol. 34, no. 1 (Jan.-June 1943), pp. 29-48.

Electric Busbars, Wrought Iron. Bus Construction of Welded W.I. Pipe, J. A. Gerber. Elec. World, vol. 120, no. 12 (Sept. 18, 1943), pp. 64-65.

Electric Cable, Joints. Low Tin Solders for Cable Joints, F. O. Wollaston. Elec. Light & Power, vol. 21, no. 9 (Sept. 1943), pp. 36-41.

Electric Welding, Arc. Complicated Assemblies, L. T. Kennedy and E. Wenzel. Steel, vol. 113, no. 16 (Oct. 18, 1943), pp. 92, 124.

Electric Welding Machines. Resistance-Welding Controls, H. L. Palmer. Gen Elec. Rev., vol. 46, no. 9 (Sept. 1943), pp. 507-510.

Electric Welding, Resistance, Refrigerated Tips. Super-Cooled Spot Welding Electrodes, C. C. Titherington. Iron Age, vol. 152, no. 16 (Oct. 14, 1943), pp. 94-98.

Electronics. Theory and Design of Electronic-Control Apparatus, W. D. Cockrell. Am. Soc. Mech. Engrs.—Advance Paper no. 35 for meeting Nov. 29-Dec. 3, 1943, 10 pp.

Fans, Maintenance and Repair. Repairing Induced Fan Blades by Arc-Welding, L. L. Bradley. Industry & Power, vol. 44, no. 10 (Oct. 1943), pp. 71-72.

Guns, Manufacture. Stamping Presses, Resistance Welders, Brazing Furnace Make "Forged" Gun Parts from Steel Strip, G. W. Birdsall. Steel, vol. 113, no. 15 (Oct. 11, 1943), pp. 194-196, 198-200, 212-214, 216, 219-220, 222, 225-226.

Health Aspects of Welding, A. G. Cranch. Can. Metals & Met. Industries, vol. 6, no. 10 (Oct. 1943), pp. 35-37, 44.

Iron Castings. Cast Iron Rod Comes Back, A. Havens. Am. Mach., vol. 87, no. 21 (Oct. 14, 1943), pp. 108-110.

Jigs and Fixtures for Arc Welded Mass Production, V. J. Brooking. Steel, vol. 113, nos. 17, 18, 19 (Oct. 25, 1943); pp. 80, 82, 84 (Nov. 1); pp. 102, 104, 139 (Nov. 8); pp. 119-20, 122.

Materials, Conservation. Wartime Salvage Welding, H. Thomasson. Miner, vol. 16, no. 9 (Sept. 1943), pp. 36-40.

Metals Fatigue, Testing. Endurance of Machines Under Few Heavy Loads, J. O. Almen. Metal Progress, vol. 44, no. 3 (Sept. 1943), pp. 435-440.

Metals. Hard-Facing Applications and Techniques. Welding Engr., vol. 28, nos. 9, 10 (Sept. 1943), pp. 31-33; (Oct. 1943), pp. 54, 56, 58, 60.

Metals. Hard-Surfacing Procedures Help to Stretch Equipment for War. Industry & Power, vol. 44, no. 10 (Oct. 1943), pp. 66-67, 94.

Metals. Hard Surfacing Prolongs Life. Rock Products, vol. 46, no. 10 (Oct. 1943), pp. 58-59.

Metals, Sealing. Silver as Bonding Material. Mech. World, vol. 114, no. 2961 (Oct. 1, 1943), pp. 393-394.

Motor Bus Axles. Homogenized. Bus Transportation, vol. 22, no. 10 (Oct. 1943), pp. 54-55.

Oil Well Pumping, Equipment. Life of Walking Beam Rockers Extended by Hard-Facing Technique, E. Sterrett. Oil Weekly, vol. 111, no. 10 (Nov. 8, 1943), pp. 78-80.

Ordnance. Canadian Armament Redesigns Conserve Critical Materials and Increase Production, J. Montagnes. Product Eng., vol. 14, no. 6 (June 1943), pp. 327-332.

Oxyacetylene Cutting. Fundamentals of Oxy-Acetylene Cutting. Oxy-Acetylene Tips, vol. 22, no. 4 (Oct. 1943), pp. 117-125.

Oxyacetylene Welding. Wartime Plant Maintenance. Oxy-Acetylene Tips, vol. 22, no. 4 (Oct. 1943), pp. 133-135.

Oxy-Gas Cutting. Carving Steel with Oxygen, F. Waldo. N. Y. Univ. Quadrangle, vol. 14, no. 1, (Sept. 1943), pp. 16-18.

Oxy-Gas Cutting. Flame Cutting Applications Greatly Expanded by Improvised Setups, F. Waldo. Steel, vol. 113, no. 16 (Oct. 18, 1943), pp. 82-83, 121-123.

Penstocks Welded on High Dam, G. L. Yetter. Western Construction News, vol. 18, no. 7(July 1943), pp. 306-308.

Power Plant Equipment. Welding Uses Pounds to Save Tons, R. C. Fitzgerald. Power, vol. 87, no. 11 (Nov. 1943), pp. 746-747, 781a-782a.

Preheating of Carbon Steel Necessary for Good Welds. Western Metals, vol. 1, no. 7 (July 1943), p. 27.

Research, Welding. Oscillographic Measurements in Spot Welding Research, R. A. Wyant. Instruments, vol. 16, no. 8 (Aug. 1943), pp. 478-479, 510-511.

Research. Welding Research in U.S.A. Brit. Motor Ship, vol. 24, no. 285 (Oct. 1943), pp. 224-225.

Sheet Metal Working. Pressing and Welding. Elec. Rev., vol. 133, no. 3424 (July 9, 1943), pp. 35-39.

(*Continued on page 45*)

War Emergency Codes for Unfired Pressure Vessels*

By E. R. Fish†

AS FREQUENT reference will be made to the A.S.M.E. Boiler Code Committee and for the information of those who may not be familiar with its procedure a brief explanation may be of service. The Boiler Code Committee was set up by the American Society of Mechanical Engineers in 1911 but it was not until 1914 that the first Code was finally agreed on and published. This covered only boilers carrying a pressure of over 15-psi. gage. It rapidly became a generally accepted standard for the construction of boilers.

The Unfired Pressure Vessel Code was not issued until 1925 and has also been generally accepted and, to a lesser extent than the Boiler Code, been adopted as a legal standard.

Because of apparent lack of clarity in some of the wording considerable difficulty was encountered in interpreting the Code so that it became necessary for the Code Committee to meet rather frequently to answer such inquiries. These answers were issued as Interpretation Cases for general distribution so that all interested persons would have the same information.

Furthermore, developments of new materials, and progress in the art of designing and building boilers and pressure vessels generally continued to advance. In order that the Code might not become obsolete it was necessary for the Code Committee to take cognizance of these advances and to make corresponding changes in the Code provisions. Many cases were issued to take care of these problems, practically all of which have been embodied in later issues of the Code.

As the petroleum refining industry requires many pressure vessels that are subject to peculiar conditions, the American Petroleum Institute desired to have a Code that was better adapted to its special problems than the A.S.M.E. Code on Unfired Pressure Vessels. In order that there might not be conflicting discrepancies between two such Codes a Joint Committee of A.P.I. and A.S.M.E. members was appointed. This Committee prepared what is known as the A.P.I.-A.S.M.E. Unfired Pressure Vessel Code, which is quite similar to the A.S.M.E. Code.

This A.P.I. Code has been changed from time to time to parallel the changes that are made in the A.S.M.E. Code so that generally speaking the two are quite similar.

Work is now going along on a revision of the A.S.M.E. Code which it anticipates will be so arranged as to be acceptable to the petroleum industry and thus do away with two Codes that have, it must be confessed, been the source of some inconveniences.

It will be well also to explain the classification of unfired pressure vessels. Of these the A.S.M.E. Code sets up three different classes identified by the Code paragraph numbers under which they may be constructed.

Par. U-68 requirements are substantially the equivalent of boiler drums.

Par. U-69 requirements are not as stringent as Par. U-68 with respect to the test and examination of welded joints and is also limited to use for vessels of $1^1/_2$ in. plate thickness and to carry 600 lb.

Par. U-70 has still less stringent requirements. U-70 vessels may be used only in restricted service and in relatively thin plate.

However, in the new revision above referred to and following the A.P.I.-A.S.M.E. Code, these classes will be entirely eliminated and differences in the construction and the examination methods will be provided for by means of preferential stress allowances for the more carefully constructed vessels.

It is anticipated that this Revised Code will eliminate many of the objections to the present Code.

Emergency Requirements

Relaxation in construction requirements should be made only when it is generally agreed that reasonable, if not absolute, safety is not sacrificed. It is recognized that failures of pressure vessels in a plant producing essential war materials may cause damage and delays far in excess of the value of any material that may have been saved in the attempt to conserve materials.

Because of the firmly rooted ideas that have prevailed from the time when materials and workmanship were far inferior to present-day practices, it is difficult to rid oneself of those prejudices and feel assured that lighter construction may be essentially as safe as it would have been under the older and heretofore accepted standards.

Every one, of course, is familiar with the efforts that the War Production Board has made to effect savings in critical materials of all kinds, the low carbon and low alloy steels adapted to welded construction being the ones in which we are particularly interested.

More than a year ago the WPB made a direct and vigorous appeal to the A.S.M.E. Boiler Code Committee to afford some relief respecting the design of boilers and pressure vessels. Indeed, the plea was so urgent that the Boiler Code Committee departed from some of its usual procedures to work out a change that would help the condition. By cutting some of the usual red tape, a special case, No. 968 to which further reference will be made, was promulgated in June 1942 and slightly revised the following September, which reduced the required thickness of boiler parts by about 20%, which is a real contribution to the conservation of materials. However, certain restrictions were set up that had to be observed if advantage was taken of the case.

* Presented at the Annual Meeting, A.W.S., Chicago, Ill., Oct. 18 to 21, 1943.
† Engineering Consultant, Boiler Div., The Hartford Steam Boiler Inspection and Insurance Co.

The War Production Board in its Limitation Order L-299 says, "No person shall produce, fabricate, or deliver any power boiler except as permitted by paragraph (*d*) hereof, having a greater metal thickness or quantity of steel than needed to meet the minimum thickness requirements of Section 1 (the Power Boiler Code) of the American Society of Mechanical Engineers, Boiler Construction Code, Addenda thereto and interpretations thereof including Case No. 968.

"No person shall accept delivery of any power boiler which he knows or has reason to believe was produced, fabricated, or delivered in violation of the provisions of this order."

The item (*d*) heretofore referred to cites certain exceptions that are not pertinent to this discussion.

When the easement of Code requirements affecting boilers was made, it was because that was the paramount issue with the War Production Board just at that time and was prompted by the contemplated tremendous power requirements for the synthetic rubber program then in process of development.

As soon as the boiler matter was acted on, the question was raised respecting a similar provision for unfired pressure vessels of which there would also be required a great number of many kinds for a great variety of purposes.

Of its own volition, the Boiler Code Committee proceded to make a companion provision for unfired pressure vessels that resulted in the adoption of Case 979 in July 1942, which is similar to Case 968 in all essential details. This Case was somewhat modified in September 1942 at the same time that the changes aforementioned were made in Case 968.

In what is essentially a construction code, the War Production Board in its circular "War-Time Standards for Design and Construction of Commercial Cylindrical Shell and Bare Tube Tubular Heat Exchangers" issued November 15, 1942, set up a standard to "expedite production and to conserve critical materials." It further states that "the standards set forth are generally consistent with the safety requirements of the A.P.I.-A.S.M.E. and A.S.M.E. Codes."

Also tube gages may be modified where working pressure would require heavier gage tubes when calculated by the A.S.M.E. formulas.

While these standards are intended for application particularly to heat exchangers it is indicated that pressure vessels for whatever use might be constructed in accordance therewith.

Materials

In order to meet existing conditions, the American Society for Testing Materials has made numerous changes in many of its specifications, designating these changes by the letters "EA" prefixed to the usual "A" or "B" designations, signifying "Emergency Alternate." Since all of the A.S.M.E. Code Specifications are identical with or based on A.S.T.M. Specifications, the Code Committee has promptly taken action to authorize the use of these emergency specifications, of which there are now 16, in the construction of the Code pressure vessels. These specifications cover a considerable variety of materials including carbon and carbon alloy castings for various purposes including welding, seamless and welded boiler tubes of low carbon steel as well as alloy steel, alloy nuts and bolts, chrome and chrome nickel steel plates for welded pressure vessels, copper, copper alloy condenser tubes and brass castings. While many of these changes are not very great it is necessary to have official recognition of them so that inspectors will be authorized to permit the application of the Code Symbol. Case 981 provides such authorization.

Ordinarily these new and revised A.S.T.M. specifications would ultimately be adopted by the Code Committee but in view of the immediate need the above action was taken with more than usual promptness.

The U. S. Navy Department Bureau of Ships issued a plate interim specification 48S5, of which Grade M is welding quality, for use in the construction of pressure vessels. This specification provides for the rolling of plate on strip mills which makes the identification of separate plates difficult under war manufacturing conditions.

The specification was the subject of a meeting of a Special Committee of the Boiler Code Committee and the Plate Committee of the American Iron and Steel Institute at which time the matter was discussed at length. The Subcommittee's report to the Code Committee contains the sentence, "It would be difficult to show that this material is appreciably inferior to Specification S-1 flange quality. It has been amply demonstrated that this material welds satisfactorily."

The chemical characteristics of this specification are slightly different from those of the usual specifications but since a very large tonnage of material was being made it would be highly advantageous to utilize this steel for pressure vessels, and thus avoid the complications at the mill that arise when changes in specifications are made.

In reply to an inquiry respecting the use of this material the Code Committee ruled by Cases 959 and 978, that for the duration of the war emergency and until these cases are annulled, the plate and the use thereof referred to in the inquiry are acceptable for Code vessels under Paragraphs U-69 and U-70 with some special protective provisions, particularly covering identification stamping.

Under this specification speed of rolling plates is greatly increased over the usual rolling procedure and since the quality of the material to start with is practically the same as if it were used for rolling sheared plates, there is no sacrifice of safety.

Special Materials

If in order to meet some unusual condition, many of which are constantly coming up in the course of wartime manufacturing developments, it is desired to make use of a special material which is not provided for in the Code and the use of which involves the need for observing special precautions, action by the Code Committee is necessary.

For instance, it was recently asked if it is permissible to construct vessels in accordance with Paragraph U-68 using high tensile manganese molybdenum steel conforming to A.S.T.M. Specification A204–38 with some modification. This material had a tensile strength of from 90,000 to 105,000 psi. and a yield point of 55,000 psi., the maximum carbon being 0.22%.

After being referred to and reported on by a Subcommittee, the Code Committee's action in Case 941 was to the effect that it is permissible to use this material with certain restrictions. Other cases authorizing the use of special materials are Case 897 for Chromium Nickel Steel, Case No. 905, Copper Chromium Nickel Steel, and Case 989 Chromium Steel, all with appropriate restrictions.

As additional illustrations of the way in which the Boiler Code Committee is modifying Code provisions in order to meet the war situation, the actions in several other cases may be cited.

The inquiry in Case No. 985 reads: "In view of the difficulty in securing forged or cast butt welding and slip-on flanges and nozzles, will it be permissible to use flanges on necks fabricated by welding, in the construction of boilers, piping, and unfired pressure vessels?"

The beginning of the reply is, "It is the opinion of the Committee that it is permissible to build up flanges or necks by fusion welding for use in the construction of boilers, piping and unfired pressure vessels provided," then follow several requirements that must be observed.

Case 983, the inquiry of which reads, "In view of the restrictions affecting the availability of the usual grades of bolting material will the following additions and extensions of Tables P-7 and U-2 meet the intent of the Code?

"1. Heat-treated carbon steel bolting material.
"2. Manganese steel bolting material.
"3. Bolting steel to suitable National Emergency Specifications.
"4. Increase of temperature limits on Type B-7 of A.S.T.M. Specification A193–40T to 1000° F."

The reply to this inquiry reads:

"Certain of the steels listed are new and complete data as to the high temperature strengths are not available, making it necessary for the Committee to exercise judgment in establishing the acceptability of these substitutes. It is the opinion of the Committee that the following additions and extensions of Tables P-7 and U-2 are conservative, based on the advice of the Subcommittee on Ferrous Materials and other competent metallurgical experts and may be accepted as meeting the intent of the Code."

Then follows the specific listing of the several specifications together with the allowable working stresses at various temperatures.

The inquiry in Case No. 990 says, "There is no specification in the Code covering iron and steel gas welding rods. Since A.S.T.M. Specification A251–42T for iron and steel gas welding rods has been released, may rods complying with that specification be used in the construction of Code vessels?

Specification S-63 for iron and steel arc-welding electrodes is identical with A.S.T.M. Specification A233–40T. However, that specification has been revised and is now designated as A233–42T. May electrodes conforming to these latest A.S.T.M. Specifications be accepted for use in Code Construction?"

The reply reads, "It is the opinion of the Committee that gas welding rods complying with A.S.T.M. Specification A251–41T and arc-welding electrodes complying with A.S.T.M. Specification A233–42T will be acceptable for use in Code construction."

Code requirements make it necessary for each plate used in Code vessels to bear an identifying stamp. However, conditions became such that it was not always possible to obtain properly stamped plates and so Case No. 931 was set up, the inquiry of which reads, "In view of the present emergency that makes it practically impossible to obtain certain materials made in accordance with Code Specifications, may materials available in jobbers' stocks or elsewhere be used in Code boilers and other vessels?"

The reply says in effect that, as a temporary expedient, material that might conform to certain specifications but for which mill test reports are not available may be used provided samples are taken and the physical and chemical properties shown to be in substantial compliance with the appropriate specification applicable to the purpose for which the material is to be used and if the material is acceptable to the inspector.

This provision makes it possible to use good unstamped material and thus utilize what might otherwise be frozen stock.

Flanges

At its last meeting, September 10th the Boiler Code Committee approved a report from its Subcommittee on Bolted Flange Connections recommending the acceptance of the American War Standard for Pressure-Temperature Ratings for Steel Pipe Flanges, Flanged Fittings and Valves promulgated by the American Standards Association Committee B16C5 in January 1943. This revision of the 1939 Standard liberalizes the pressures and temperatures at which steel flanges of standard dimensions may be used.

Factors of Safety

Since they introduce some radical departures in boiler and pressure vessel design it is appropriate to discuss in more detail Cases 968 and 979 before mentioned. It has long been accepted practice to design boilers and pressure vessels with a so-called factor of safety of 5, which simply means that the maximum allowable working stress is taken as one-fifth of the minimum of the range of the tensile stresses given in the specification, which figure is, of course, reduced by whatever joint efficiency has to be used.

In effect, but not specifically, Case No. 968 reduces this factor of safety from 5 to approximately 4. However, in so doing a number of restrictions were set up, one of which is a mandatory additive thickness above that calculated, of 0.1 in. except that for thicknesses of 0.4 in. this addition needs be only $1/4$ of the calculated thickness.

Another provision that departs from usual practice is the requirement that openings in shells requiring reinforcement shall have that reinforcement applied uniformly on the inside and outside of the shell although openings in heads may have the reinforcement on one side only.

The case also provides an easement in the gage of tubes required for water tube boilers.

Boilers built in accordance with this case may have the Code Symbol stamp applied but in addition the letter "A," signifying Alternate, must accompany the Symbol. This further identification was deemed advisable because of the probable desirability, after conditions become normal again, of avoiding confusion on the part of inspecting agencies and State and City Departments as to the exact design of the boilers constructed under present conditions.

Case 979, which applies to unfired pressure vessels only, is practically the same as Case 968 although there are some differences.

The required additive thickness in this Case is $1/6$ of the calculated thickness, but need not exceed $1/16$ in., to allow for general corrosion. However, attention is called to the need for a greater corrosion allowance when vessels are used in corrosive service.

The requirement for the uniform distribution of reinforcement inside and outside of a shell is omitted in this case. Stresses due to hydrostatic test and other stresses which appreciably increase the stress over substantial sections of the shell must be allowed for in determining the thicknesses of the various parts.

The Case, No. 897, that provides for the use of chrome nickel material is referred to in Case 979 whereby the same increase in allowable working stresses is permitted as in the case of the usual grades of steel.

Non-Ferrous Materials

There is very little provision in the A.S.M.E. Code for the use of non-ferrous materials in the construction of pressure vessels but few are now constructed of these very critical materials. However, Cases No. 934 for copper, 935 for copper nickel alloy, 945 for Aluminum Bronze and 994 for Aluminum Manganese alloy specifically provide for the use of such metals in Code vessels.

The characteristics of these materials are so different from those on which the Code is largely based, it is probable special sections will be made to provide for them. Indeed this is being done in connection with the revision of the A.S.M.E. Unfired Pressure Vessel Code now in progress.

Safety of Personnel

While the subject of safety of persons is not strictly pertinent to this paper it is well to call attention to the effort that the American Standards Association is making to set up standards for safety in electric and gas welding and cutting operations. This is being effected by Committees from the International Acetylene Association, the National Electrical Manufacturers Association and the AMERICAN WELDING SOCIETY. This Safety Code is well along toward completion. It outlines in considerable detail the precautions that must be taken in handling welding equipment of all kinds and what is necessary for the protection of workmen.

As respects pressure vessels there is this significant statement—"Ventilation is a prerequisite to work in confined spaces. When welding or cutting is being performed in a confined space such as the interior of a boiler or inside a tank, the welding or cutting equipment shall be left on the outside. An attendant stationed outside shall observe the welding operator at all times and in case of emergency immediately shut off the gas or electric current and render such other help as the occasion warrants."

"Where a welding operator must enter a confined space through a manhole or other small opening, means shall be provided for quickly removing him in case of emergency. Safety belts and life lines used for this purpose shall be so attached to the operator's body that the body cannot be jammed in a small exit opening." In addition there are a number of other suggested precautions for the protection of welding operators.

In Conclusion

While it should be emphasized that conservation of personnel, property and materials is of paramount importance, hasty decisions, even in these strenuous times, are not justified if safety in operation is thereby prejudiced, for safety is the prime objective.

The Code Committee endeavors to give just as prompt attention as possible to inquiries. Usually it is not possible to make quick offhand decisions, but in especially urgent circumstances, some of the usual procedures have been by-passed in an effort to expediate action.

In a brief paper of this kind it is not possible to go into many details. The purpose has been to point out what the AMERICAN WELDING SOCIETY, the American Society of Mechanical Engineers Boiler Code Committee, the American Petroleum Institute, the American Iron and Steel Institute, the American Standards Association and others are doing in cooperating with governmental agencies in this supreme effort of our country to preserve our heritage and to bring, as well, peace, prosperity and happiness to peoples everywhere.

Discussion on "War Emergency Codes for Welded Pressure Vessels"

By D. S Jacobus*

IN meeting the desires of the Federal Authorities that the rules of the Boiler Code be amended to conserve critical materials, particular attention has been given to the element of safety. In most cases the thickness of the plate material called for by the amended rules is less than by the old rules but improvements in the design of vessels built under the amended rules will make them as safe as those built under the old rules. In any event, the inspectors discontinue the use of a vessel when it deteriorates to an extent that makes it approach the margin of safety so that the only question that might be raised is whether vessels built under the revised rules will have a long enough life in service.

The life of vessels built under the new amended rules should approximate that of the older vessels as an allowance for corrosion and deterioration has been made which calls for the thinner shells of new vessels to be of nearly the same thickness as by the old rules and which provides a reasonable margin for the thicker shells which will insure a long life under proper service conditions. The new rules are much better than the old in providing well-balanced designs and in removing certain inconsistencies.

Mr. Fish has taken a leading part in developing the new rules and I am sure the interests of the users and manufacturers, as well as of the Boiler Code Committee will be safeguarded under his guidance as its Chairman.

* Hon. Chairman, A. S.M.E., Boiler Code Committee.

Rolling Mill Maintenance and Production Welding Problems*

By Theodore W. Morgan†

General Maintenance

WHILE the maintenance and production welding problems and operations at the Butler, Pa., Division of the American Rolling Mill Co. may be small when reflected against those of the many larger steel mills throughout the country, they are equally urgent. This is particularly so in Butler where we are in full-scale war effort.

Accordingly, in our smaller way, these problems must be met promptly and solved speedily, so that production of many end products made from Armco's various grades of iron for our military forces, such as those illustrated in Fig. 1, will not be delayed. In no way do we wish to contribute to the losing policy of "too little and too late."

To do this has been equally difficult for us as for others. The Selective Draft for Military Service has drawn upon us in the same proportion as elsewhere. Our Welding Department has contributed its share in labor losses to the armed forces. We have been forced to draw upon older and, frequently, far less experienced help and, like other industries, have recently found it necessary to introduce women into our mill. A suggestion that such would occur certainly would have been ridiculed several years ago.

Our Butler Division employs in the neighborhood of 3000 people in all departments. Its plant facilities consist of open-hearth furnaces, one bloom or slab mill with 4 rows of ingot heating or soaking pits, 1 wheel works for pressing and rolling railway car wheels, a locomotive and boiler shop in the same building as our welding shop and one strip mill. The strip mill includes a Universal 36-in. strip mill, 4 slab heating furnaces, four-high hot reduction mills, two continuous normalizing furnaces, a stainless steel continuous pickling unit, 4 four-high tandem cold reduction mills, several single-stand four-high cold reduction mills and a group of 3 continuous box anneal furnaces. It will be readily seen that these facilities require a consistent maintenance program.

The Welding Department is a division of our Maintenance Department. Its functions are to aid in maintaining production, reducing costs, producing a quality product and maintaining facilities. In the 16 years of the writer's service it has grown considerably from what was practically the absence of a department. In 1927 there were but 2 gas welders and 1 arc welder in the Locomotive Department which was equipped with one 200-amp. generator for the purpose of weld build-up on armature shafts.

Fig. 1—A Few of the End Products Made from Armco Steel, on Display in the Shop

Today we have a Welding Department consisting of 35 combination arc and gas welders, 30 scarfers, 3 crane operators and 9 helpers. One assistant foreman and 7 leadermen provide supervision. The department's services are available at all times, in that, like the mill, it works 3 turns, 7 days per week. The combination welders cover all shops: open hearth, slab mill, strip mill, wheel works, galvanizing units, finish mill and the machine, pipe, boiler and locomotive departments.

Our equipment now consists of 14 arc-welding generators, one of which is the original 1927 200-amp. machine, three 300 amp., and the balance all 400 amp. An Oxygraph, four Radiagraphs and a special slab-cutting machine motivated by a Radiagraph adequately solve our machine gas-cutting problems supplemented, of course, with a full complement of manual oxyacetylene cutting and scarfing torches.

All machine gas-shape cutting is conducted in this main welding shop, using the Oxygraph for such work as shown in Fig. 2. Portable Radiagraphs may be moved about the mill for operation wherever required.

As is the case in all steel mills, our points of operation are scattered over a large area. While most of the job welding and cutting is done in the main welding shop, we have found it expedient and economical to establish several outlying small welding shops at stations convenient to heavy maintenance work points. These shops are equipped for oxyacetylene and arc welding, oxyacetylene manual cutting and are provided with a welding table. One shop is located in the machine shop and

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* Presented at the Annual Meeting, A.W.S., Chicago, Ill., Oct. 18 to 21, 1943.

† Welding Supervisor, The American Rolling Mill Co.

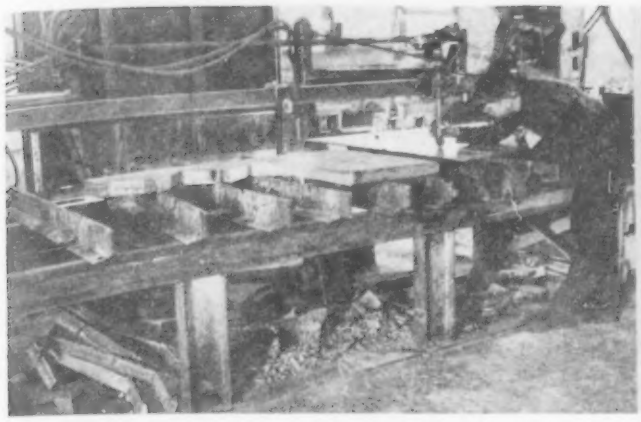


Fig. 2—All Shape Cutting Is Done in the Main Welding Shop, Using an Oxygraph for Such Work as Shown Here

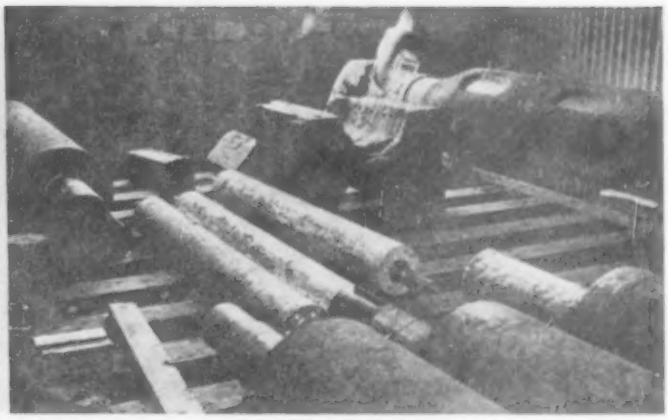


Fig. 3—Building Up Worn Surfaces on a Separator, Using Carbon Arc for Depositing the Bronze Overlay. Large Rolls in Foreground Are Table Rolls, Also Built Up by Welding

two, one at each end, in the strip mill. Localizing our welding service has saved measurably the otherwise attendant cost of handling work pieces to and from the main welding shop. Figure 3 provides a view into the activities at these stations where building-up of slab mill table rollers and separators, on the journals and in the separator box, is in progress. In Fig. 3 the welder is working on the separator. The large bearing is brass and is built up with the carbon arc. The large rolls are table rolls, the smaller ones are for the galvanizing unit. Our combination welders necessarily are skilled in all types of welding, brazing, heating and cutting, as we encounter every kind of casting, high and low carbon and alloy steel. The storage racks and trays in the corner of our machine shop, shown in Fig. 4, indicate the volume of parts to be maintained in this particular department.

While we are discussing maintenance in the machine shop we must mention the service provided by metal spraying. Savings amounting to hundreds of dollars have been effected by the employment of our Metallizer gun and outfit for the reclamation of various worn surfaces such as pump shafts, the alumetizing of box anneal furnace covers and the building up of armature bearings as shown in Fig. 5. No stripping or rewinding of the armature is necessary to accomplish this reclamation, and only the roughening of the bearing surface is required to provide an anchoring base for the sprayed metal.

Slab Mill—Slab Splitting

At Butler we have a slab mill but do not have a billet mill. Several years ago we received an order for 50 tons of ingot iron $3^3/_4$- by $3^3/_4$-in. billets, 24 ft. long. In view of the small tonnage we decided to cut these billets from Armco slabs, $3^3/_4$ in. thick, 37 in. wide and 26 ft. long, employing a No. 4 Radiagraph on a track and a single machine cutting torch. We found this not quite satisfactory as the cut sections warped and required straightening, resulting in excessive cost.

Four machine cutting torches were then mounted on a 5-ft. long bar, $1^1/_2$ in. square, and all mounted on the Radiagraph. First the ends of the rolled slabs were cropped using a Radiagraph with a single torch. Then the four-torch unit was set up as seen in Fig. 6. As the slab sides were uneven it was necessary to trim the edges first with outside cuts. Subsequent cuts were made by moving the torches toward the center of the gantry bar.

Repeated orders for the same material in 400-ton lots for welding wire stock made it essential that a speedier method be developed as the 4-torch arrangement neces-

Fig. 4—Variety of Parts Stored in Racks and Trays Indicate the Volume of Work Done in the Welding Department

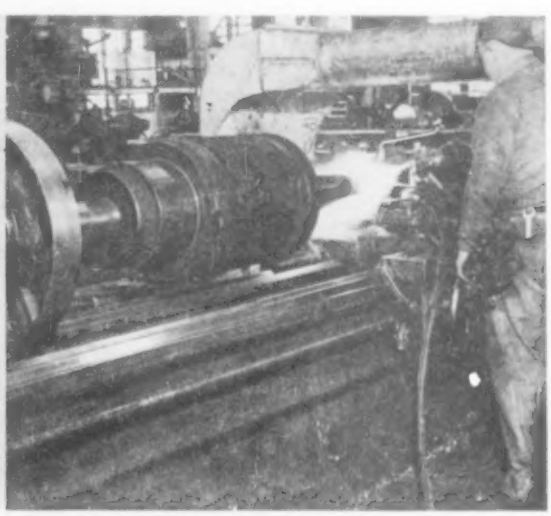


Fig. 5—This Building-Up Operation on an Armature Bearing Is One of Numerous Parts Reclaimed by Metal Spraying

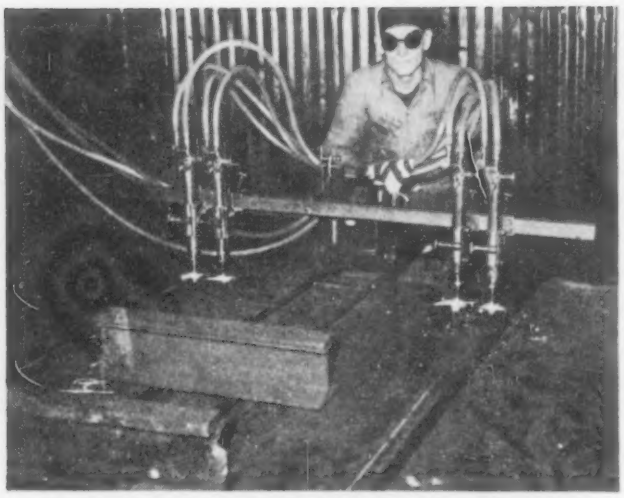


Fig. 6—The Second Setup for Splitting Slabs Into Billets Was This 4-Torch Device. Torches Were Shifted Toward Center of Bar to Complete the Slab Splitting Operation

sitated repositioning the track, the machine and the torches for splitting the entire slab.

A carriage was fabricated from tube, plate, an extended torch bar and grooved wheels. Two slabs were positioned on the floor at a low level and utilized for bases, with ample space between their parallel edges to accommodate the maximum width slab rolled. Two 1-in. square bars were mounted in diamond position on blocks and securely tack welded, one on each slab, as rails. The Radiagraph track was also tack welded in parallel position so that the Radiagraph could push or pull the carriage as desired. Employing 4 torches and traveling at a speed of 9 in. per min, approximately 8 slabs per 8-hr. day were split in this manner.

Later, to prevent wheel binding we replaced one grooved wheel with a flat wheel. The grooved wheel provided alignment on the one side, while the flat wheel on the opposite side allowed come and go resulting from heat expansion. As the volume of orders for these special billets increased soon thereafter 6 more torches were added. This permitted the complete splitting and trimming of a slab with 10 torches in one pass, as illustrated in Fig. 7. In 1942 better than 9,330,000 lb. of Armco ingot iron were cut in this fashion.

Slab Scarfing

Slab scarfing is, to a greater extent, conducted in our wheel works where we operate 3 shifts, 7 scarfers to each. The work is done in a slab field rather than on beds. To a lesser extent a certain amount of slab scarfing is conducted in our slab mill where 3 shifts are in progress, 4 scarfers to each. The scarfers in the wheel works are under the supervision of the Welding Department. Those in the slab mill are supervised by the Superintendent of the slab mill, but the Welding Department cooperates and aids in coordinating this activity.

Here is one of the outstanding examples of the accelerating employment of women for operations heretofore believed exclusive to male activity. At present we use both men and women for this work, and have found the women far more adaptable than we expected. This is hot, heavy work, requiring real stamina in even a man.

Our training for women scarfers follows a strict pattern. First, they are given two days of class work to learn the reason for the operation, to train them to identify quickly inspectors' markings and to recognize the dif-

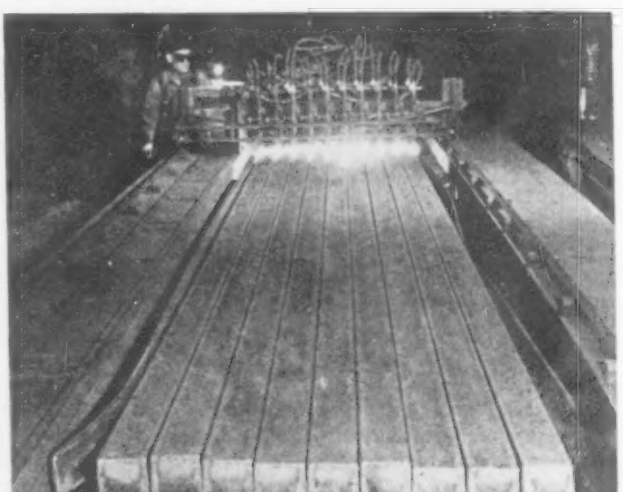


Fig. 7—Final and Present Setup for Slab Splitting Uses 10 Torches, Driven by a Portable Radiagraph, to Complete the Job in One Pass

Fig. 8—This Mill Employs a Number of Women for Scarfing, as Shown Here. After 3 Weeks They Can Handle Approximately the Same Tonnage as Male Operators

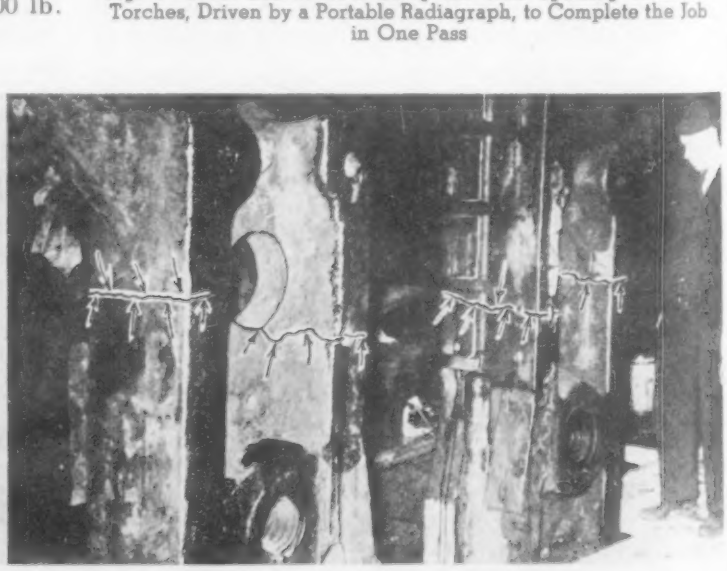


Fig. 9—Slab Mill Housing, Fractured in Both Legs, Before Weld Repairing Was Begun. This Photo Was Slightly Retouched to Show the Breaks

ference between minor surface markings and harmful pipes, scabs, seams and the like. They are then taken into the mill and, with an unlighted scarfing torch, are taught torch balance, and coordination of torch, arms and body movement while walking at the proper scarfing speed. After being taught these principles, followed by the lighting, operation and care of the torch, they are then permitted to light the torch and to practice scarfing of scrap steel. We have found that, after 3 weeks, the best of these girls can scarf approximately the same tonnage of slabs as the men. Four are shown at work on the slab field in Fig. 8.

Slab Mill Housing Repair

About a year ago we had a breakdown on one of our 34-in. Universal mills, due to fracture in a 68,000-lb. slab mill housing casting.

Three thousand men depended on this mill for work and at the same time were working on war production 100%. The foundry could not deliver a replacement housing in less than 3 to 5 mo. As this mill can produce 60,000 tons of steel per month, it is evident that it was highly essential that it be returned to operation in the shortest time possible.

The housing, at the point of fractures, is an H-section of approximately 6-in. thickness flange and web; the web being bored with an 11-in. diameter hole to accommodate a hydraulic cylinder which is used to pull the side rolls in and out. The flanges are 18 in. wide and from the outside to outside of flanges is $28^1/_2$ in. While it is not certain where the fracture started, it traveled through a $2^1/_4$-in. drilled hole in the flange and proceeded to the bottom of the 11-in. hole. Then it again started from the center of the opposite side of the 11-in. hole and proceeded in a fairly straight line to the outside of the opposite flange, causing a complete break in both sides, and separating the housing in two pieces. Both housing legs broke in approximately the same manner. The breaks are illustrated in Fig. 9.

Naturally, with a war production schedule to fulfill, the mill required our advice as to when we would place the rolling mill back in service. A quick survey of the necessary procedure was made and a working schedule for the repair was anticipated. It was estimated that we could complete this work in 15 days, or slightly less, unless unforeseen developments occurred. We broke down each stage of the planned procedure into task classifications, allocating an estimated number of working hours to each. In nearly every instance we were not only able to maintain this self-appointed schedule, but also to excell it by finishing each particular task ahead of schedule. The accumulated gains resulted in our turning out the job in a period of 14 days, and, in actual progressive working hours, in 13 days. During this period, and during the welding stage, we filled in 2437 linear inches of weld metal, or 896 lb. of 0.10–0.12 carbon, 0.45 manganese, 0.035 phosphorus, 0.035 sulphur, 0.07 silicon electrode, the equivalent of A.S.T.M., A232–42T, E-6010 electrode. The metal deposition required 121 hr., 484 machine-hours and 600 man-hours; the excess man-hours over machine-hours being accounted for by spell welders. The cost of this repair, excluding the dismantling and reassembling of the mill, but including all welding and machine shop hours, was $1,658.50. A new housing, if it could have been obtained, would have cost $12,850. While we have since purchased a spare housing, to meet the recurrence of such an emergency, the repaired housing continues to provide day-in-and-out service.

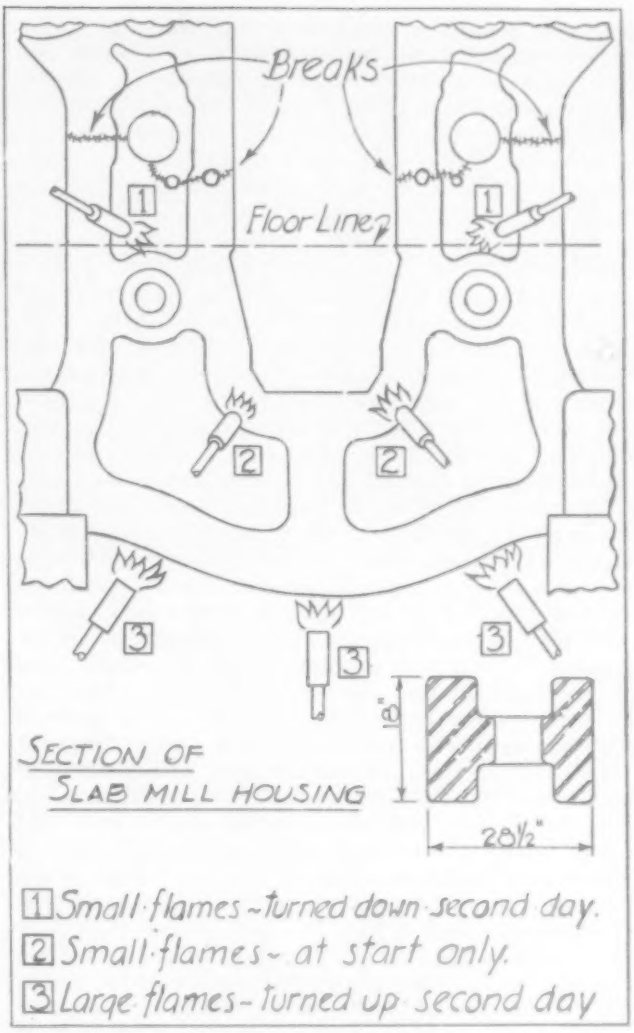


Fig. 10—Natural Gas Burners to Preheat the 68,000-Lb. Casting Were Mounted in the Positions Shown Here, and Controlled as Indicated

We first stripped the mill of all outside and inside gears, rolls, etc., and then cleaned off all grease and dirt. Due to the open areas about the mill a temporary shelter was built around the entire housing to keep the welds free of cold drafts. The housing was then braced to allow for repair in position. Such allowed us to leave the foot bolts in place, holding the bottom and, at the same time, take advantage of the bottom and top tie bars which are 12 in. square at the bottom and 16 in. square at the top. The tie bars, connected to the outside housing, furnished excellent means for holding the broken housing horizontal. We then put a 2-in. bar through the vertical screw box, in the center of the housing, put a plate on the top of the housing, threaded the end of the bar and fastened its bottom to a structural frame which, in turn, was fastened to the bottom of the housing. This held the housing in a true vertical position.

Natural gas burners were next installed in the positions shown in Fig. 10, but so placed that they could be moved about to control the preheat temperature and to retard dissipation of the heat from the welded section. While this was being done, welding circuits were installed, acetylene and oxygen were moved to the job and 4 welding machines were checked for the operation.

Oxyacetylene scarfing, preheating, arc welding, slow cooling and machining, in the sequence given, provided

the fastest possible method for restoration. This procedure appeared to be the only practical routine considering the confined working conditions encountered in repairing the housing in position. The similarity of the breaks on each leg of the housing permitted the same program for both the right- and left-hand sides. For the purpose of illustration, we will discuss and illustrate the application on the left-hand leg only. The view of Fig. 9 shows the extent and position of the fractures in both legs. For immediate visualization of their character and path, this photograph has been retouched in black and white outline and directional arrows.

Plates, $1^1/_2$ in. thick, were then welded on each face of the flanges, as shown in Fig. 11, and the broken housing was checked with a perfect housing for exact alignment. To assure alignment check being maintained throughout the operation, tram points were placed on both housings, in vertical and horizontal position, so as to observe any evidence of horizontal movement. The necessary pin gages were made to fit the different tram marks. The job was now ready for scarfing out the webs. This was a delicate, difficult job because if superfluous heat were transmitted into the casting it would expand excessively and trouble would be experienced in realignment. Therefore, scarfing proceeded slowly and heat transmission was carefully controlled. The fact that both legs were broken permitted scarfing to proceed for a short period on one leg and then on the other for an equivalent period, alternating back and forth until completion. The procedure consisted of starting at the inside of the 11-in. diameter opening, in the web, and gouging toward the flanges. This was carried through for the entire thickness of the web on both sides of the hole. These gouges terminated at the flanges, or slightly beyond, as indicated in Fig. 11. The gouges were then cleaned with a hand-grinding tool. Considerable time was saved by cleaning all scarfed surfaces to a bright finish. Small globules from the arc would be dissipated as spatter and would not adhere to the bright finished surface as readily as to an unfinished scarfed or hand-cut surface.

Welding then proceeded as seen in Fig. 12. Our welding machines were set at 150 amp. and a $^5/_{32}$-in. electrode was employed. The small size aided in eliminating some undesirable heat and prevented undue internal strains. The welding procedure consisted of depositing one horizontal or stringer bead for the full length of the flange section, and then cleaning the bead and peening with a round-nosed air-operated peening tool. Peening speed was carefully checked to prevent overpeening. The weld was again cleaned with a wire brush before the next bead was deposited. This sequence continued until there was about 2 in. depth of weld metal on the inside of the flange section. A heel was thus formed and the $1^1/_2$-in. thick positioning plates were then removed with safety.

Scarfing then proceeded on the outside surfaces of the flanges, as seen in Fig. 13. The same sequence routine was followed, i.e., scarfing, cleaning by grinding, stringer bead welding, cleaning, peening, wire brushing, welding, etc. Bead reinforcements were carried through well above and below on the flanges and around their entire surfaces, as shown in Fig. 14. Four welders were employed, one on each outside face of the H-section and one on the inside section. The same procedure was carried out on both legs which allowed control of heat distribution and avoided internal strains due to uneven heating. Care was taken to deposit no more than sufficient metal in the 11-in. holes so that machine work could be held to the minimum.

During the welding, two boxes were made of galvanized sheet iron, their inside dimension 4 in. larger than the housing itself. This allowed room for packing insulating material around the housing. These were immediately installed around each leg upon completion of welding to keep the casting from cooling too rapidly. They likewise provided an annealing effect. After normal temperature was attained the boxes were re-

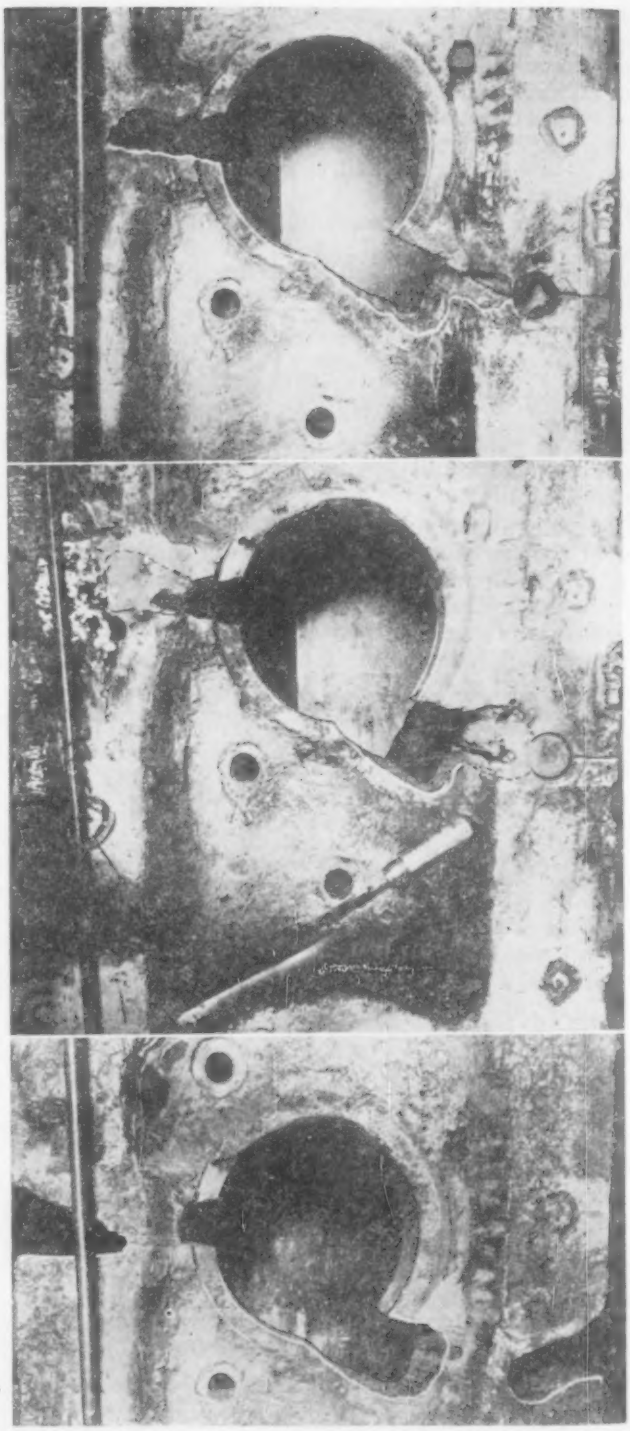


Fig. 11 (Top)—Initial Gouging Was Carried Through to the Flanges, Then Cleaned with a Hand Grinder. Note That Heavy Plates Were Welded to Flanges for Support and to Maintain Alignment

Fig. 12 (Center)—Appearance of Housing Leg After Welding Inside Gouge, and Before Gouging Out the Balance of the Crack at the Right. Electrodes Used Were $^5/_{32}$ In. Diam.

Fig. 13 (Bottom)—Outside Flange After Removal of Tie Plate and Scarfing of Crack. Both Legs Were Treated in the Same Way and at the Same Time

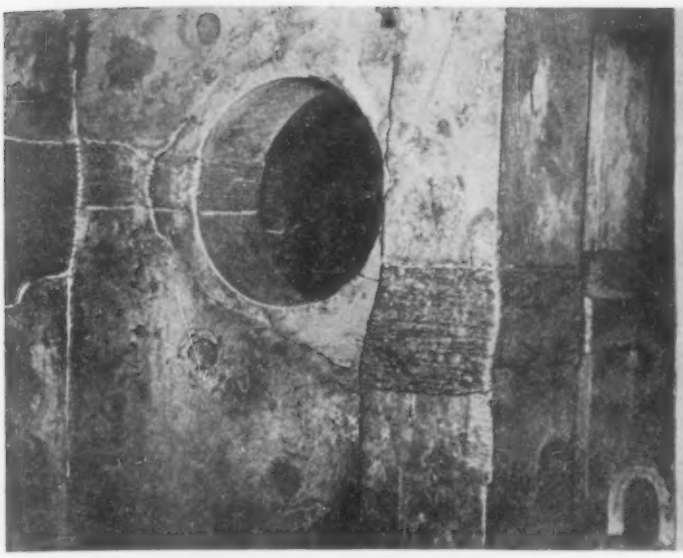


Fig. 14—View of the Finished Weld, Showing the Amount of Reinforcement Welding. Electrodes of E-6010 Specification Were Used, 896 Lb. Applied to the 2 Legs

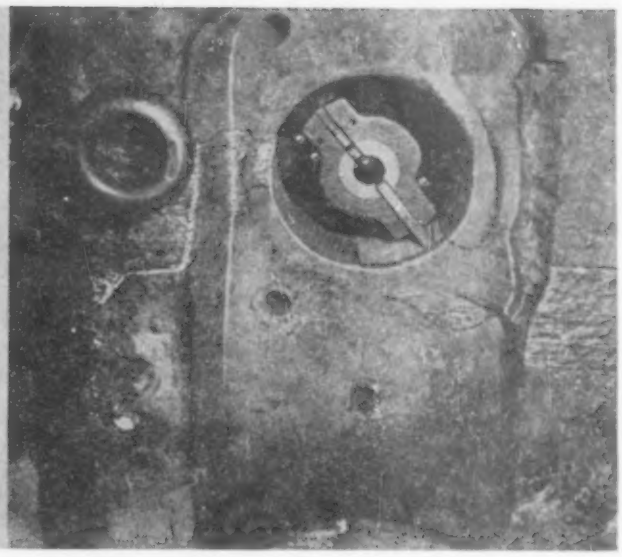


Fig. 15—Appearance of One Leg of Housing Casting, with the 11-In. Diam. Hole Partly Machined. The Housing Was Restored to Service After This Operation

moved and the housing taken to the machine shop where the excessive weld metal within the 11-in. diameter holes was removed as shown in Fig. 15. On completion the housing was installed in operation.

Open-Hearth Sloping Backwall Furnace

At least 5 of the sloping backwall type open-hearth furnaces have been built at our Butler plant. Originally all of our furnaces were of the older straight-back type but these are gradually being replaced with the sloping backwall type as fast as their normal life is expended. The gradual clogging up of checkers and the lack of checker draft eventually cause them to be lost to service.

A straight backwall furnace will burn out faster than the sloping type. Direct heat on the backwall causes the bucks, frequently made of structural shapes, to

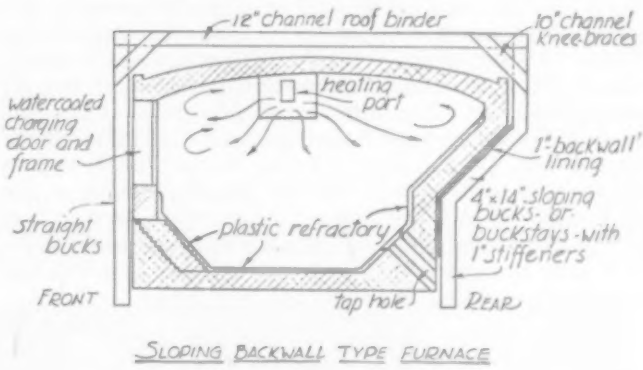


Fig. 16—Cross Section of Sloping Backwall Open-Hearth Furnace. Five Such Furnaces Have Been Fabricated at This Mill, and Others Will Be Built as the Old Straight-Back Furnaces Need Replacement

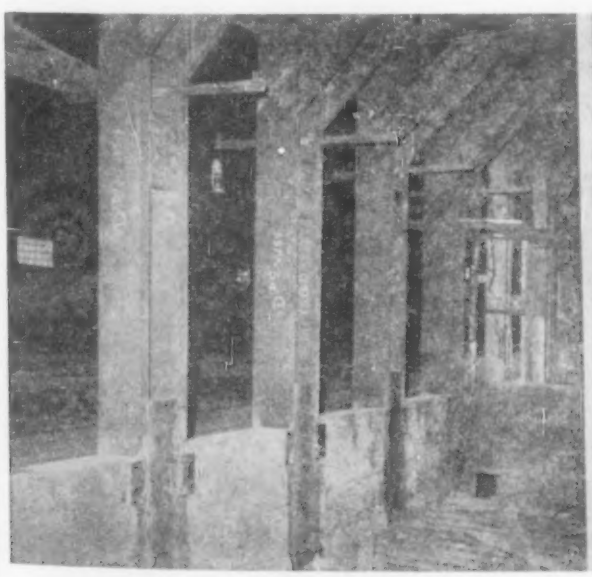


Fig. 17—Inside View of Door Sill Casting Section of Fabricated Sloping Backwall Furnace, During Construction

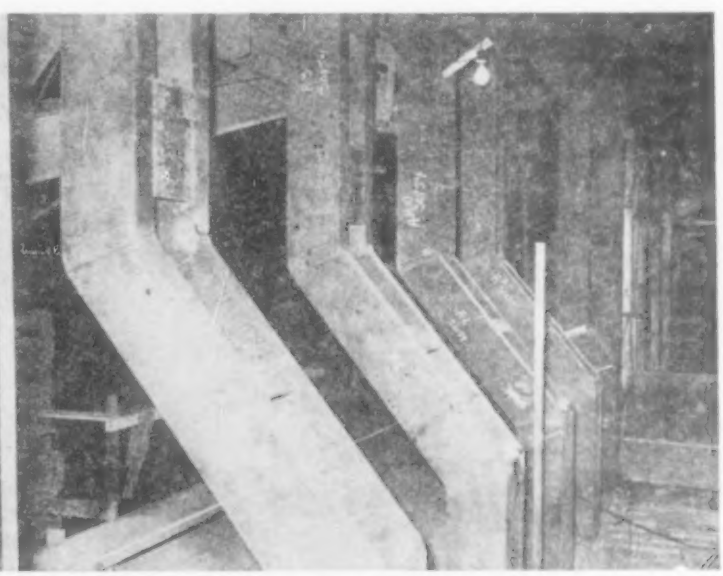


Fig. 18—View of Rear Buck Stays Taken from the Inside, During Erection of Fabricated Open-Hearth Furnace

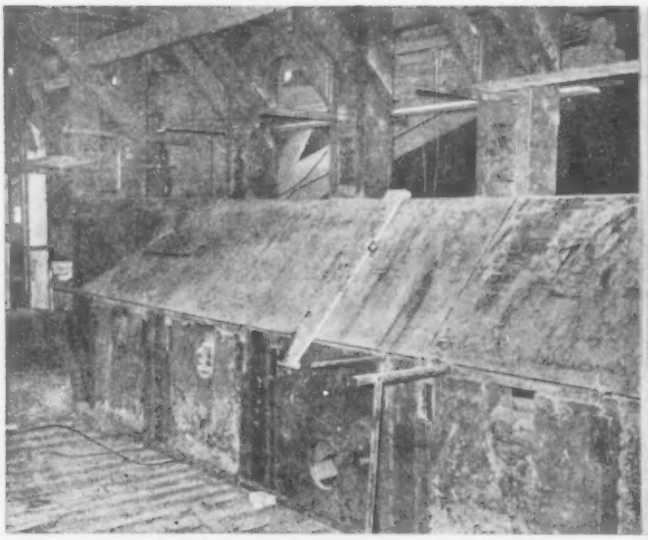


Fig. 19—Furnace Backwall Lining, Made of 1-In. Rolled Plate

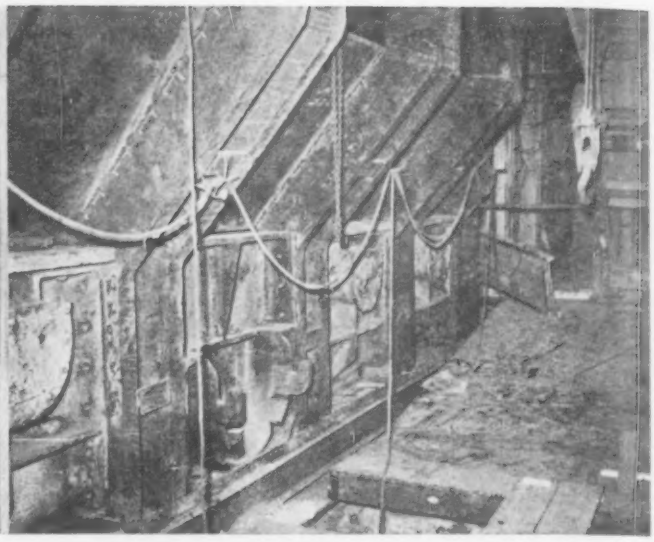


Fig. 20—Rear of Furnace Under Construction, Showing Back Castings and Tap Holes

bulge, necessitating continuous repairs. The modern sloping backwall types have buck-stays made of solid 4 x 14-in. sections which offer strong resistance to distortion and can be economically framed with welding. Figure 16 illustrates a typical cross section of the newer design. Various stages of erection are shown; Fig. 17 shows the door sill casting from the inside; Fig. 18 a view of the rear bucks from the inside. In Fig. 19 we see the 1-in. thick backwall lining in place while in Fig. 20 our view is of the back, on the outside, looking at the back castings and tap holes. An interior view of one of the older straight wall furnaces is given in Fig. 21. It is fully bricked-in similar to the manner in which the new sloping backwall furnaces will be finished.

Fig. 21—Fabricated Sloping Backwall Furnaces Are Finally Bricked-in Similar to This, Which Shows One of the Old Straight-Back Furnaces

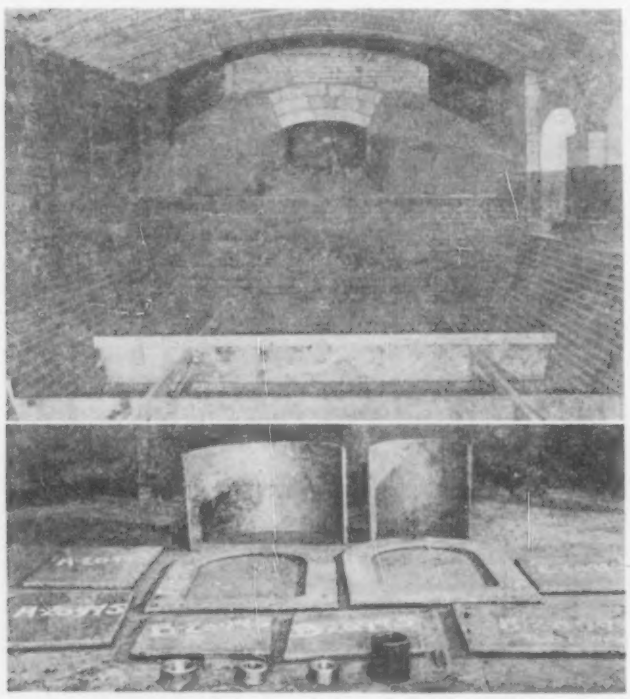


Fig. 22—These Are the Flame-Cut Parts Which, When Welded, Make Up the Open-Hearth Nose Cooler Shown in Fig. 23

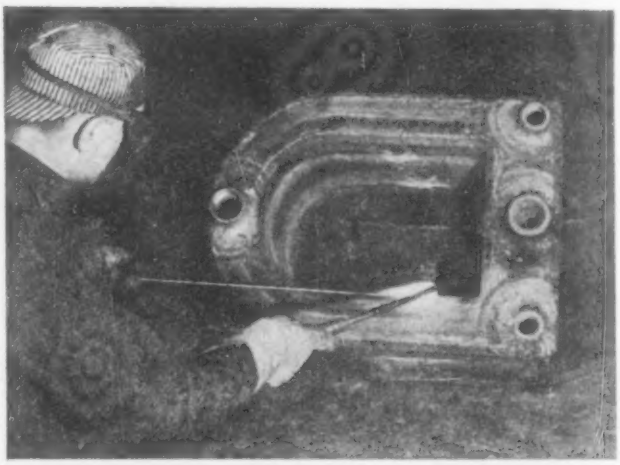


Fig. 23—Using an Oxyacetylene Welding Torch and High-Test Rod, the Nose Cooler Is Welded in 15¼ Hr. All Welds Are Continuous and Watertight

Nose Cooler

In order to keep the burner nose cool in the open-hearth furnace, a nose cooler chamber is built for each installation. Even though these burners are water-cooled, the intense heat created in the furnace will cause the burners either to sag in the middle, or, frequently, bend straight up toward the roof. Outside adjustment cannot offset this condition. It was necessary to devise additional protection without installing added and burdensome water-cooling equipment, since every gallon of water employed increases the fuel cost.

The open-hearth nose cooler is a wholly gas-cut and gas-welded job although, in some instances, the arc has been employed for welding this item. It has been found, in this instance, that time and costs for gas or arc are about the same. Figure 22 shows the various parts, as flame cut, laid out prior to assembling. Using the torch, and a high test rod, Figure 23, the units are assembled in 15¼ hr. welding time. There are 417 linear inches of welding on this unit. All welds are continuous and water tight.

Port Cooler

We have also been fabricating port coolers for the open-hearth furnace, as illustrated in Fig. 24. By

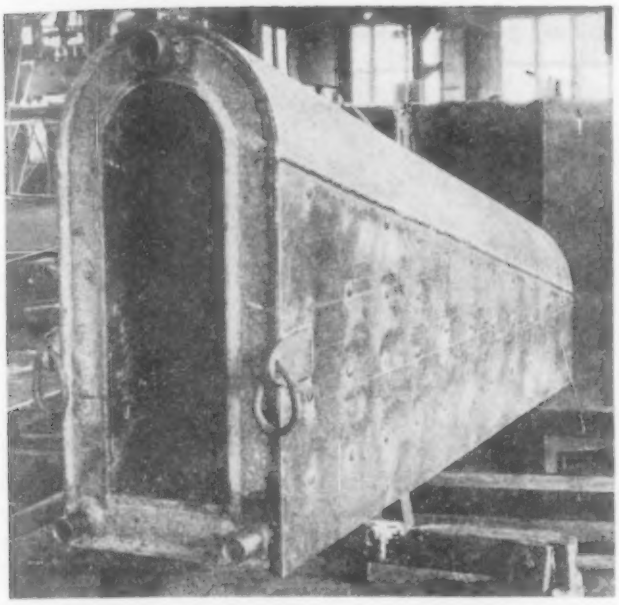


Fig. 24—This Fabricated Open-Hearth Port Cooler Is Another of the Parts Commonly Fabricated by the Welding Department. It Takes 35 Man-Hours to Build

using these port coolers, in conjunction with the nose cooler, we can reduce the size of the pipe employed for the burner. We save water as well, the securing of which is quite a problem at our Butler, Pa., plant.

The outside and inside walls, bottoms and formed hoods, as well as the ends, are flame cut from $^3/_8$-in. thick plate. Staybolts, made from 1-in. diameter steel, are threaded throughout and span the cooling water jacket on the sides—inside to outside walls. Pipe of $1^1/_2$ in. diameter, welded in at the head, serves for water inlet and outlet. The ends are positioned with a recess allowing fillet welding throughout. This port is tested under pressure at 150 psi. and takes about 35 man-hours to fabricate.

Miscellaneous Items

We endeavor to solve as many problems as we can with oxyacetylene cutting, either manual or machine, and arc welding. Today with scarcity of materials, delayed deliveries and all of the other uncertainties attendant with the securing of replacement parts, fabrication on the job is practically compulsory if uninterrupted production is to be maintained. And in more than a few instances we have found that not only can we effect economies in this fashion, but, more frequently than not, secure a stronger and more serviceworthy product. The wheel works furnace door, and its parts, is a typical example. It takes but 3 hr. to make from $^1/_2$-in. plate and several lengths of standard small angle bar and strap.

Another example is the wheelbarrow wheel. Securing replacement wheels for the hundreds of barrows necessary around a steel mill is now practically out of

Fig. 26—Bulk Oxygen Supply Is Received by Means of 40,000 Cu.-Ft. Capacity Trailers Such as This, Shown Connected to the Master Valve Control

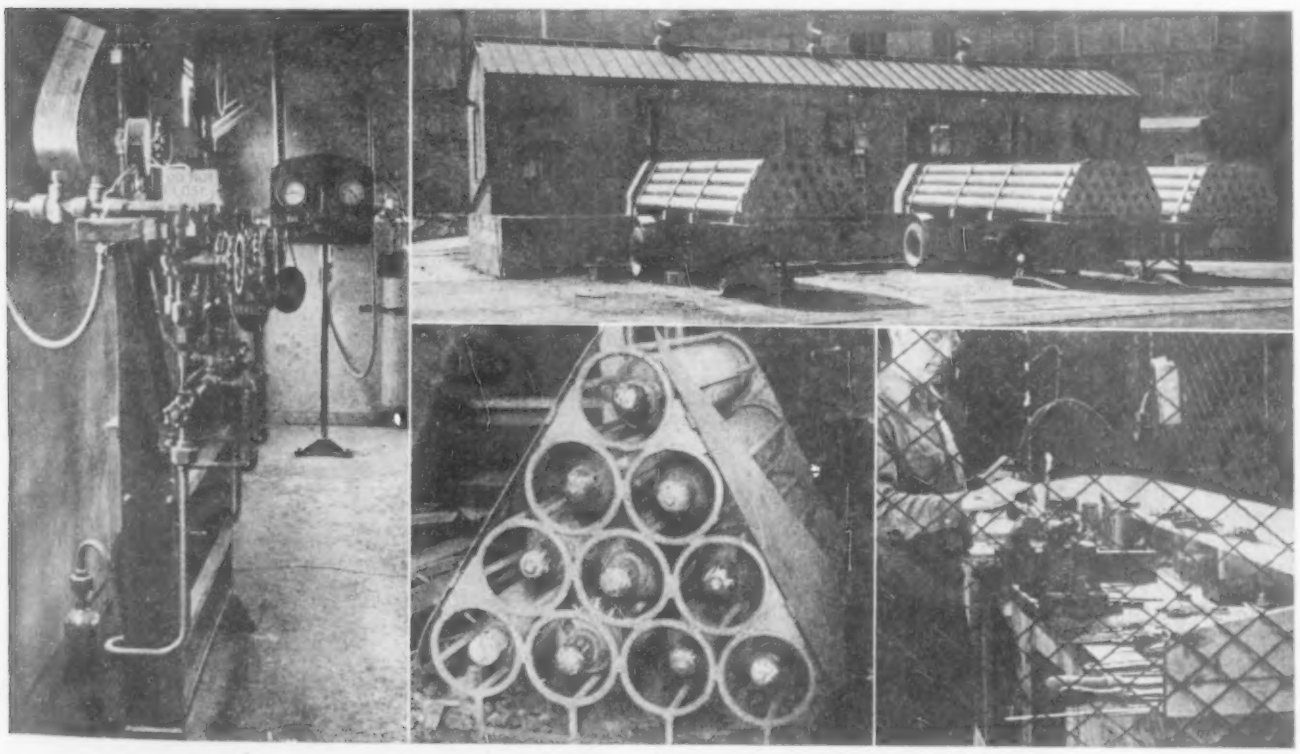


Fig. 25—Central Control Valves and Regulators. Oxygen Trailer Trucks Feed Through These Controls to the Pipe-Line Distributing System Throughout the Plant

Fig. 27—This Portable Rack Provides Protection to Individual Oxygen Cylinders, Which Are Occasionally Needed for Operations at Remote Points. Hinged Doors Are Swung Back in This View

Fig. 28—In This Apparatus Repair Department, Oxyacetylene Welding and Scarfing Apparatus Is Inspected Periodically. Repairs Are Made Promptly if Defects Are Disclosed

the question. Wooden wheels are, of course, impractical. At one time, during the period of rubber availability, we tried rubber-tired wheels. But the customary conditions about steel mill floors and grounds, such as pitted and pocked concrete, scrap steel, etc., caused excessively rapid deterioration and destruction so that these were abandoned. The fabrication of steel wheels is now standard practice. These wheels are 15 in. in diameter, weighing about 10 lb. The welded axle is $1^1/_2$ in. diameter and 7 in. long. Two hours' welding time is required per wheel. They are particularly adaptable to open-hearth use where such equipment naturally is subjected to unusually rough treatment.

Gas Distribution and Apparatus

We are very fortunate to have had installed a complete pipe-line distribution system prior to the war for both oxygen and acetylene throughout our major buildings and to points where either one or the other, or both, require large quantity supply. As a result we have effected many economies and have eliminated a large amount of cylinder handling. Our requirements in 1938 reached a volume that warranted the expenditure for a piping installation, an expenditure which was quickly written off due to the savings effected after installation.

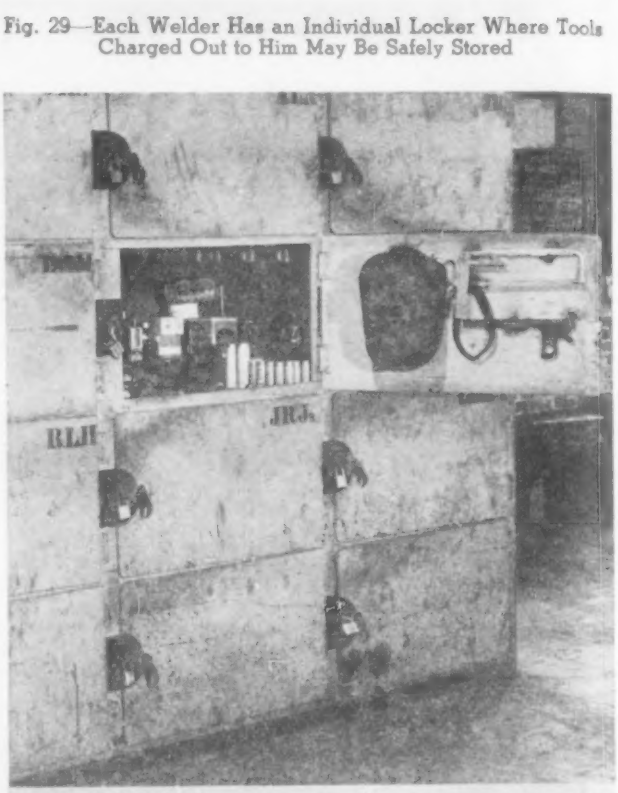
Our main oxygen line starts with a $2^1/_2$-in. supply pipe and extends, in diminishing diameter as the demand toward the end point reduces, to the welding, locomotive and boiler shop, the slab mill, open hearth, wheel department, strip mill and machine shop. The line pressure averages around 140 to 150 psi. and outlets are generally 1 in. for all drops. At the scarfing drops 80 psi. are required.

At first oxygen was supplied from 88 manifolded oxygen cylinders, in an oxygen manifold building east of, and near our Welding Department building. The manifold building was of sufficient size to allow adequate cylinder storage. Later we found it advantageous to change over to oxygen trailer track delivery, and we utilized one corner of the manifold building, shown in Fig. 25, for our trailer manifold and control. Complete control of our oxygen supply is maintained at this point. When a 20,000-cu. ft. oxygen trailer, as shown in Fig. 26, is connected to the master valve control, shown to the left in Fig. 25, and represented by the "in-service" disk, the oxygen is directed to the Flowmaster regulators, one of which is shown at the rear. Here it is reduced from the 2200 to 2400 psi. trailer pressure to the 140 to 150 psi. line pressure. A "reserve" trailer is always available for automatic cut-in upon complete discharge of the "in-service" unit.

The main acetylene line is $1^1/_4$ in. with station drops in all oxygen locations excepting in the open hearth. Only pipe-line oxygen, is needed at that point for the tapping of heats on one side and keeping ladles open on the other. The acetylene generator house is outside of the welding shop to the west. One 500-lb. and one 300-lb. double rated medium pressure generators adequately serve our need.

There still remains, and always will, a moderate need for cylinder oxygen for operations at remote and emergency points, or at points where only an occasional demand exists. To facilitate the safe and speedy handling of these cylinders, we have constructed a number of protective racks as seen in Fig. 27. A rack of this style can be lifted and handled at will with safety. It is moisture proof, as the bottom tier is sufficiently high to

Fig. 29—Each Welder Has an Individual Locker Where Tools Charged Out to Him May Be Safely Stored



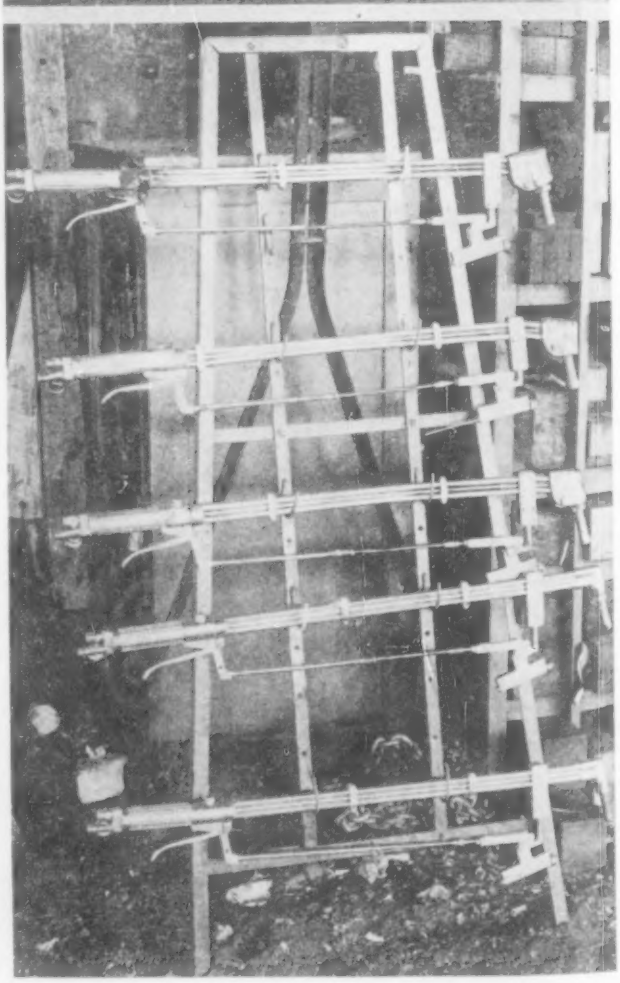


Fig. 30—In the Scarfing Fields, This Type of Rack Is Provided to Prevent Damage to Torches When Not in Use

remain above ground puddles. With the cylinders in a horizontal position, there is no danger of their being knocked over. The doors may be closed and locked when required. It is an economical unit, made of tubing and light plate, welded throughout.

Apparatus Repair and Care

Faulty apparatus may cause much unwarranted expenditure. Valuable time may be lost when the need of repair to the welding apparatus occurs after everything is all set up for an emergency repair job. This may well happen, and does, when periodical inspection of welding, cutting and scarfing apparatus is not maintained. To overcome this, all equipment is periodically inspected in our apparatus repair department, shown here in Fig. 28. Repairs are made promptly if defects are disclosed. Good work requires good tools, and, to remain good, good tools must be properly cared for. We strive to maintain each piece of equipment at its peak efficiency.

We endeavor to educate our employees likewise. Our welders are provided with steel lockers wherein they keep all of their own tools and equipment charged out to them. A group of these lockers is shown in Fig. 29. At the scarfing fields, where torches with starting rod attachments may be quickly injured if left about the field, racks, as shown in Fig. 30, are provided for the torches when not in continued use.

Conclusion

We have only attempted in a general way to discuss a few of the many problems we, even in our modestly sized mills at Butler, meet and try to solve. The increasing difficulties that all of us have experienced in securing replacement items during these difficult times and the imperative demand placed upon us to maintain peak and overpeak production without interruption, calls for all our ingenuity and resourcefulness. It is possible that others are faced with like problems, and if, in any way, the methods of solving any of the problems herein presented provides either an answer or a suggestion toward the answer to like or similar problems, then we will feel that the presentation of these data has been warranted.

Reclamation of Perishable Tools by Low Temperature Brazing*

By W. A. Johnson†

I AM NOT a welding engineer! I have only handled a welding torch on a few occasions. I am familiar with and understand the practical application of oxyacetylene welding only. I am a tool engineer! I do understand the application, design, manufacture, and uses and misuses of cutting tools as that is my job. It is my responsibility at Tractor Works of the International Harvester Company. I am not going to attempt to tell you, gentlemen, anything about theoretical brazing or welding. Therefore, I have selected the subject for my talk as "Reclamation of Perishable Tools by Low Temperature Brazing." I intend to show you the possibilities of increased research, study and application of the oxyacetylene torch with low-temperature alloy rods as can be used for repairing and reworking damaged, broken, worn-out, obsolete and surplus cutting tools and putting them back to work again instead of the customary practice of discarding them as worthless scrap.

Our welding engineer brought to our plant and guided the adoption of this low temperature brazing method to the repairing and reworking of cutting tools. This welding engineer, Mr. Theodore Russell by name, was given the cold shoulder at first. Many said it couldn't be done.

This welding engineer proved that it could be done. For the past four years, we have studied and developed new applications for the use of this low temperature brazing process on the repairing and reworking of cutting tools.

At first, our progress was slow. Failures were experienced. We became discouraged, but we kept on trying and began to have moderate success. When success was felt and the possibilities were presented to the management, the way was paved and facilities were made available for further research and development. By the time the war broke, we had attained greater success. In tooling up for war products, our cutting tool requirements were found to be varied and quite extensive. With long deliveries and delays in obtaining the needed cutting tools, it was necessary to add an extra effort to our tool reclamation activities in order to obtain as many of our requirements as possible. In other words, we had to be resourceful on our own in order to meet Uncle Sam's requirements for war production.

Every possible talent was thrown into this program. We were literally forced to reclaim and rework existing inventories of these so-called scrap tools. We are proud of our success and the results of our added efforts.

Since man has learned how to combine iron, carbon, manganese, silicon, chromium, vanadium, tungsten, molybdenum, cobalt and other elements into a cutting

* Presented at the Annual Meeting, A.W.S., Chicago, Ill., Oct. 18 to 21, 1943.

† International Harvester Co., Tractor Works.

tool steel and then machine it into a fine precision cutting tool, should he discard this tool because it is undersize, broken or obsolete? From the conservation angle alone, this is a waste. From the practical common-sense angle, it is not necessary. There are three ways in which these available cutting tools, in whichever form they may be, can be put back to work: first, the conventional manner of regrinding in the hard; second, build-up welding; three, low temperature brazing. Since this is a welding society convention, I am going to refrain from discussing the conventional manner of regrinding in the hard. Since build-up welding is still in the experimental stages, I am only going to briefly outline the research work which has been going on in this field and what is hoped to be accomplished by this method through continued research. Since low temperature brazing has been highly successful, that is the picture I wish to present and discuss today.

Having discarded conventional regrinding as unappropriate for this meeting, let me briefly outline what has been done in the build-up welding field. Many efforts have been made in recent years to develop a welding technique and a welding rod which could be used for building up and replacing broken teeth in cutting tools. A great many welding alloys have been tried, but generally, their temperature of application has been too high. The oxyacetylene torch has been used in these experiments with several commercial welding alloys. We have had sufficient success to warrant further research in this field. What we hope to discover is a welding rod with a sufficiently low melting point so that the heat of application necessary with the oxyacetylene torch will not anneal the rest of the cutter and will also leave a built-up or replaced tooth of sufficient hardness necessary for a cutting tool by air hardening.

Our research indicated that the preparation of the tool, technique of the welder and the grinding of the welded cutter are important problems which have to be solved. Others are working on these problems and we feel that one of these days the right combination will be discovered which will make this salvage method practical. The advantages of such a process are enormous. The savings are large. A cutting tool engineer would welcome its successful use. We are working at present with a large tool steel manufacturer who is attempting to develop such a welding rod and the technique necessary for its use.

The low temperature brazing process, as we have successfully applied it, consists of brazing tool steel in its various forms of fabricated cutting tools just below those temperatures harmful to the hardness of high-speed tools. As mentioned before, this process has yielded cutting tools which could not have been purchased in time to keep production schedules. We have put cutting tools back to use for a normal tool life expectancy. Cracked slitting saws, broken milling cutters, broken flat, round and multiple spline and keyway broaches, extension reamers and drills made from two short ones, two short tool bits butt brazed together, repaired broken dovetails on forming tools and many other examples of this method of tool reclaiming have been realities at Tractor Works.

Steps common to this type of tool reclaiming are:

1. Preparing the surfaces to be joined. If an even break has occurred, we find it better not to grind the joint ends.
2. Clean surfaces thoroughly with carbon tetrachloride using a soft bristle brush, thus removing dirt.
3. Coat with autochemic flux the surfaces to be brazed
4. Apply an oxyacetylene torch to the joint ends.
5. Apply the brazing material until it flows freely through the joint.
6. Grinding or filing for removal of excess material.
7. The sharpening of the tool.

Sounds simple, doesn't it? Well, it is but not quite as simple as described. There are many tricks and refinements in this process which have to be developed by experience. I will mention a few that our welder has learned.

In most cases it is necessary to thoroughly preheat a tool before attempting brazing. This preheating can either be done by the torch before starting actual brazing or a small furnace with heat regulation may be used. Depending on the kind of tool, the preheating temperature should be between 600° and 800° F. The preheating is necessary to avoid setting up stresses in the tool which might cause it to break. After brazing, it is advisable to place the tool back in the furnace and allow it to cool off gradually or place it in mica or asbestos.

There are several rods used in low-temperature brazing. They are all chiefly an alloy of copper, zinc, nickel, phosphorus, cadmium and a medium amount of silver 40 to 60%. Their melting points vary from 800 to 1600° F. The alloys used in tool brazing range in melting points from 1175 to 1300° F. Now, these temperatures are very near the drawing temperature of high-speed tools. The welder must learn the correct manipulation of his torch and heat it so as not to harm the tool. He must not soak his heat. He must work from the center of his tool out so as not to cause stresses in the outer edges of the tool. He must direct his torch on his welding rod and use it as a thermometer for his working temperature. If he knows the melting point of his rod, which is given by the manufacturer, he can gage his torch application accordingly.

The autochemic fluxes used must be entirely liquid and active at temperatures below the flow point of the brazing alloy.

The drawing temperature of most high-speed tools is between 1000 to 1100° F. Therefore, as mentioned before, a soaked heat must be avoided by the torch. To anneal a high-speed tool, the tool must be heated for a prolonged time at a temperature above its critical point. This is not going to happen in repairing tools as only a few minutes' brazing heat is necessary.

Not every welder can braze high-speed tools. He must be an experienced hand and one who knows what he is about. Most welders can be trained and become adept at tool brazing with practice.

Most tools require the use of an alignment fixture while brazing. These fixtures need not be elaborate but should be accurate. The strength of a correctly brazed joint depends upon its thickness. The strongest joint thickness seems to be 0.0015 in.

The one outstanding phase of our use of low temperature brazing is that of making new tools from both scrap materials and new materials. Milling cutters have been a bottleneck at Tractor Works on one of our war contracts. We have actually made mill type and back-off type, plain, side and form milling cutters by brazing hardened prefabricated blades into a heat-treated machine steel body. This method has not only saved time but high-speed steel, as well as keeping production going.

Tools reclaimed and fabricated by the aforementioned procedure do actually have, in most cases, the same life as new tools.

During the past year, we put into use by the various tool reclaiming methods 14.5% of our total cutting tool expenditures. In our opinion, this is an enviable record.

I wish to elaborate on the aforementioned outstanding phase of our low temperature brazing application. That is, the making of milling cutters by brazing hardened prefabricated blades into a heat-treated machine steel body. This application consists of machining a milling cutter hub from a mild alloy steel in a suitable manner for receiving the prefabricated hardened high-speed blades. The blades are then placed into the hub and peened in place. After assurance has been made of the proper setting of the blades, they are then brazed in place by the low temperature process. Scrap milling cutter blades can be used for this application as well as new blades. After the blades are brazed in place, the cutter is then ground in the conventional manner. In the case of a backed-off form milling cutter, it is necessary to form grind blades with a straight back-off so as to insure all teeth doing their required work. This form grinding is not a simple process and many tool grinding men will discourage its use. It can, however, be done by the use of simple template type fixtures which an experienced tool grinder understands the use of.

There are several advantages in being able to make a milling cutter by this method:

1. More blades per inch of circumference, thus, less chip load per tooth.
2. Increased feeds and speeds due to additional blades, thus, increased production.
3. Versatility of application.
4. Being able to help yourself when conventional cutters are not available.
5. A stronger cutter.
6. Many shops do not have back-off lathes as there has been a shortage of back-off lathes in the cutting tool industry. Therefore, since these cutters can be made without a back-off lathe, you can readily see the advantage of this process.
7. We believe that the fabrication of cutters by this method could be as economical as the conventional manner.

I wish to emphasize the importance of relationship between the welding engineer and the perishable tool engineer. Neither can function successfully as an individual. The welding engineer is versatile and thoroughly familiar with the necessary theoretical and practical applications of his welding technique. The perishable tool engineer is familar with and understands the design, fabrication, use and misuses of his cutting tools. In order to successfully repair broken and worn-out cutting tools, the perishable tool engineer must make sure that he imparts to the welding engineer the necessary knowledge about the function and application of his tool so that the welder may have the benefit of this information in his repair work. In other words, if a welder should be given a broken tool and told to braze it together and he did not understand the clearance, the step per tooth and pertinent information as regards design and application of the tool, he would just merely braze the tool together and it would fail when put back to work. I cite as an example to illustrate this point a broken broaching bar. In designing a broaching bar, it is necessary to distribute the amount of stock which is to be removed by the broach evenly over a given number of teeth so as to limit and distribute the load per tooth evenly. Starting with the first tooth of a broach, each tooth becomes progressively larger toward the end of the bar. If a welder desiring to braze together a broken broach should merely place it in a fixture locating against one side of the broach and then proceeded to braze, he would have that one locating side without the necessary progressive step per tooth and the broach would not perform its required work.

On the other hand, if the perishable tool engineer did not rely on the welder or welding engineer to instruct him in the particular problems of heat control, brazing temperatures and strength of brazing, the resulting repaired tool would be unusable because of too high heat or other strictly welding failures.

I think I have made it clear that a free interchange of experience knowledge and technique is necessary and vital between the perishable tool and welding engineers.

At a meeting such as this, very little can be said and explained in regard to the proper design of alignment fixtures for holding the various cutting tools while brazing The importance, however, of well-designed, accurate and universal alignment fixtures cannot be overemphasized. Their accuracy of construction and their design for universal use are the most important items. The use of stock, mill run angle plates and clamps is not sufficient for use by a welder in repairing precision made cutting tools. We have found that approximately 8 or 10 universal fixtures are all that is necessary for the welder to have in repairing the average cutting tool used in an industrial plant engaged in the manufacture of automobiles, trucks or tractors. These fixtures should be constructed with positive clamping devices in the lower section of the fixture and spring plunger floating locating devices in the upper half of the fixture. This design is necessary so as to insure the correct joint thickness in the shortest period of brazing heat. There is no set formula which I can offer you in designing these fixtures. Your needs and requirements must be studied and the fixtures then developed to meet these requirements. Elaborate, expensive and costly fixtures are not necessary, but, as mentioned before, they must be accurate, universal and constructed of good, well-selected materials.

I believe I have covered the subject assigned to me as best I can, but wish to assure you that more detailed information can be brought out through the discussion and question period which it is my understanding is to follow. They said it could not be done at Tractor Works! You may at first feel that it cannot be done in your plant. Do not become discouraged! Try again! We have done it and you can do it, too!

Current Welding Literature

(*Continued from page 29*)

Shipbuilding, Welding. Down to Sea in Ships, with Arc Welding, C. A. Rober and W. B. Strathdee. Technique, vol. 18, no. 1 (Jan. 1943), pp. 54–58.

Shipbuilding. Welding and Cutting Developments, W. B. Cave and C. F. Crawford. Log, vol. 38, no. 3 (Mar. 1943), pp. 69, 72.

Solders, Substitutes. Safe Substitute Solder for Food Cans. Metal Progress, vol. 44, no. 3 (Sept. 1943), pp. 420–421, 454.

Steel Hardening, Oxy-Gas Process. Shorter Patent Hardening Machine for Large Circular Tracks. Machy. (Lond.), vol. 63, no. 1610 (Aug. 19, 1943), pp. 218–219.

Structural Steel. Manual Welding Technique Developed for Thick Steel Plates. Eng. News-Rec., vol. 131, no. 19 (Nov. 4, 1943), pp. 696–697.

Tubes, Steel. Advantages of Square Tubing. Product Eng., vol. 14, no. 7 (July 1943), pp. 418–421.

Water Pipe Lines. Field Welding of Steel Water Pipe, H. A. Price and G. H. Garrett. Am. Water Works Assn.—J., vol. 35, no. 10 (Oct. 1943), pp. 1295–1302.

Welders. Trading of Shipyard Welders, A. Von Drachenfels. Pac. Mar. Rev., vol. 40, no. 10 (Oct. 1943), pp. 78–81.

Welding, H. Barrett. Rock Products, vol. 46, no. 10 (Oct. 1943), pp. 56–57, 59.

Welds, Testing. Methods of Testing Welds. Oxy-Acetylene Tips, vol. 22, no. 4 (Oct. 1943), pp. 126–130.

Welds, Testing. Rapid and Accurate Inspection of Spot Welds, L L. Anderson. Metal Progress, vol. 44, no. 3 (Sept. 1943), pp. 433–434, 462.

The Job Shop—Yesterday and Tomorrow*

By Fred W. Shackleton†

BACK in the late 1890's, a couple of Russians obtained one of the first known patents on arc welding. From then until the outbreak of the first World War, very little was heard of this process generally and still less in available reference books of that day, although some advancement was being made with oxyacetylene welding. It was after the close of the first World War that welding started to make progress enough to come to the attention of the man on the street. Structural steel shops could be induced to furnish some partially welded sections; storage tank shops were coming into existence; and here and there a job welding shop opened for business.

In those times the greatest percentage of maintenance work was entirely on castings—castings of a low grade or unknown analysis. We were furnished welding wire of unknown composition and far from being uniform. Occasional welding jobs that were brought to us had been originally designed for casting or fabrication by riveting. Our greatest trouble was the secretive manner in which many shops operated. Numerous operators made it standard practice to apply for, and invariably obtain, patents covering every difficult job they successfully repaired.

Others, on finding new ways of using welding and developing what might be called "procedure control," adopted a "closed door" policy, all of which seriously retarded progress.

Still, with all of this, it was the maintenance welder whose willingness to try new things made himself the proving grounds for the welding procedures of today.

Today we find the job shop still exploiting new fields, experimenting with new processes and applying new procedures in every field of endeavor. It would be impossible to determine how many thousands of war machines these shops have kept in operation. In our shop alone we had two 4-men crews work around the clock for a 5-week period to put back into operation eleven heavy-duty presses that were being used in the forming of our very popular block buster aerial bomb. It gave us a feeling of personal pride to see the production lines keep rolling and read in our local newspapers of the final results of our efforts. It would be interesting to know how many tons of high-speed and alloy steels the job shops have saved with their hard-facing procedures and silver soldering. Breakage was so high on special cutting tools in this area that in our shop we were forced to school one of our men and set aside a special corner for him to work on reclaiming broaches, milling cutters, reamers and, in fact, just about every cutting tool used in a machine shop.

Along with this exhilaration of maintenance work we are also confronted with the necessity of doing production welding—in our minds, mass production. When an operator for thirty years has been accustomed to doing one-time jobs day in and day out, an order for one hundred identical units is quite an item, and when the quantity passes five hundred units, it becomes mass production to him! We had one job that the large production plants turned down due to insufficient quantity, but kept eight local job shops busy for a 6-month period. Through our neck of the woods job shops are busy making aircraft fixtures, assembly jigs, taking up the overflow of weldments of the larger manufacturers around town and, in cooperation with the various Army Depots in the area, reworking ordnance stocks on hand, correcting past mistakes, and changing ordnance units to meet new conditions being encountered by our men across the sea. This has increased the over-all capacity of our local shops. This brings me to the point of preparing a little postwar planning.

Not only have the job maintenance shops increased their capacity by the installation of extra equipment; the same thing holds true of every manufacturer. All lines of business have installed new machinery; machinery made better, operating faster, than any we have had before; which leaves one fact standing out that when we return to normal it will be the older style trouble-making equipment that will be discarded in favor of the newer late model machines. Machinery purchased in the future will undoubtedly be made still lighter and of still higher production capacity by the use of high alloy steels and more welded construction. All of this will result in drastic reduction in the over-all amount of maintenance work available, making it that much harder for the operator to maintain his accustomed volume of business.

With this condition confronting us it will be necessary to develop new fields. Of these fields in which our shops will have the greatest opportunities for development, a smart operator will find much to do in the building of odd-shaped tanks, of which there are seldom more than one or two of a type, thereby eliminating competition of

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Fig. 1—Flame Cleaning Operation

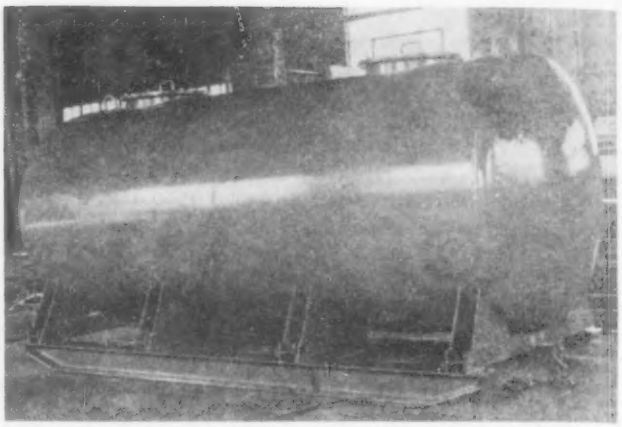


Fig. 2—Example of Special Type Tank Which Is Welded in the Job Shop

Fig. 3—Pantograph Machine Cutting 14 In. Thick King Pins

standard tank manufacturers. With the aid of a good boiler maker and a set of rolls no tank shape is too intricate for an ordinary job shop to produce.

Flame cleaning and flame hardening which require very little equipment are two fields of which the surface has been hardly scratched. Flame cleaning of structures around town, bridges, viaducts, fire escapes and others, should prove interesting and profitable work. The possibilities of flame hardening are practically unlimited. We have done considerable work in flame hardening of gear teeth, wearing pads on machine bases, pump sections, rolling stock parts on railroad equipment and sectional hardening of stamping dies.

Metal spraying is quite an old process and yet a new process inasmuch as very little effort has been made to develop this to a point of where it should be. Metal spraying of its own is of such a diversified nature that very few manufacturers could actually warrant the installation of their own equipment. Quite a bit of this type of work can be had in building up shafts, resurfacing bearings, spraying crank shafts, automotive parts, and spraying of non-ferrous coatings on tanks, piping and outside structures, to help prevent atmospheric corrosion. Quite a bit of this corrosion preventive is now being done instead of normal procedure of painting.

Possibly the most important source of business tomorrow will be flame cutting. Hand cutting as used in salvage operation would be one phase, but flame machine cutting offers the greatest possibilities. The exhilarated progress that we have all gone through today has brought

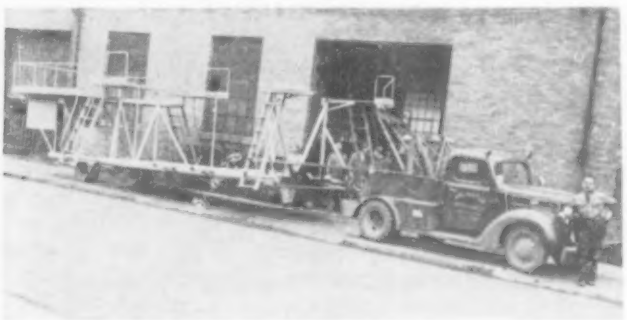


Fig. 4—Special Welded Assembly Fixture

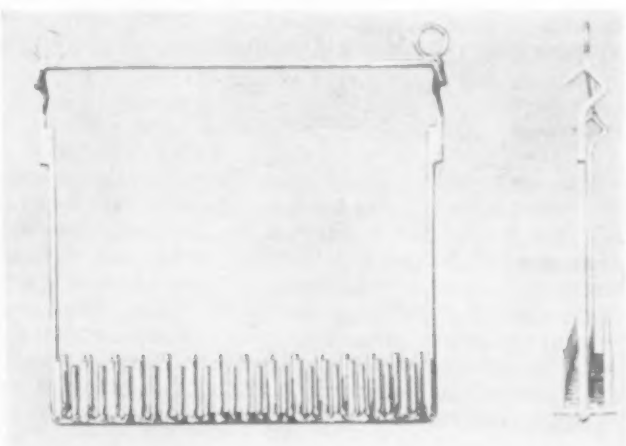
to the attention of machinery manufacturers, machine shops and die makers the importance of flame machine cutting and flame machining as never before, and the job shop of tomorrow without a pantograph type cutting machine is going to be about as bad off as the shop of yesterday without a gas engine driven arc welder. The field is unlimited to no uncertain degree—the cutting of dies; die blocks, cutting of gears and gear blanks, structural shapes, the substitution of forgings, the cutting of plate for use in replacement of castings, and many others too numerous to mention.

Welding Copper to Steel Saves Critical Metals*

By Alfred A. Wald

COPPER, being one of our most critical metals, was held to a minimum use in building this chrome plating rack by welding steel (S.A.E. 1020) to the copper hooks with copper electrodes. It was necessary that the hooks themselves be of electrolytic copper as they rest on the work bars in the plating tanks and must make perfect contact as the electricity passes through it to the work in the plating operation.

The racks carry a heavy machine part that fits these pins in the rack and the pins must be held very close as the clearance tolerance is practically nil. The maximum of distortion must be held and could only be accomplished by arc welding.



Racks Requiring Welding of Copper to Steel

* An award winner in Hobart's *Arc Welding News* Contest, sponsored by The Hobart Brothers Co., Troy, Ohio.

Quality Control in Aircraft Spotwelding*

By Nathan C. Clark†

Summary

THIS paper is a review of the steps that may be taken to assure the highest quality of spot-weld production in the aircraft industry. Several terms are defined in order to preclude ambiguity in the body of the article. It is shown that of the various procedures considered, the practical solution to the problem of quality control of spot-welding production involves three basic requirements. These are (1) standardization of the equipment and process; (2) the application of statistical control; and (3) monitoring of the spot-welding machines or non-destructive testing of the finished product. The sections on spot-welding machines are devoted mainly to the stored-energy types of equipment. The features of spot-welding machines most in need of standardization are the controls of (1) energy delivered to the weld; (2) electrode current wave shape; (3) the amount of electrode force; (4) forge time delay, if used; and (5) the shape, surface condition and life of the electrode tips, although some attention is also given to other matters of standardization. Statistical control, based on the sampling of production and subsequent analysis and prediction of quality, can be used to advantage in a number of ways: measuring the quality of the product, predicting trouble before it occurs, assuring optimum machine performance and the developing of the most economical specifications for the spot-welding process. The difference between monitoring and non-destructive testing is explained, and several proposed methods of accomplishing each of these are discussed. It is then shown that even the best possible standardization is only a close approach to perfection, and therefore that at least slight variations are certain to occur. It follows that statistical control is essential for the maintenance of high consistency and adequate strength of spot welds, and as a means of fairly measuring the quality of production, and that monitoring is required for positive proof of the strength of individual spot welds as they are produced.

An appendix is attached explaining the meanings of certain statistical parameters as applied to quality measurements of spot-weld production.

Introduction

The spot welding of the light alloys is a relatively new industrial process. Its use has expanded rapidly in the last few years, but is limited by the lack of positive assurance that every individual weld has adequate strength. Especially is this true where essential parts of the aircraft structure are involved. The object of the present paper is to present a review of the steps that may be taken to improve the quality of spot-weld production in the aircraft industry. The ultimate objective of such an improvement is to make possible the use of spot welding in aircraft structural parts with full confidence that all necessary requirements of safe design will be met.

It is not the intention of this article to compare the relative merits of various joining methods or of different kinds of spot-welding machines. It is unavoidable, however, that certain characteristics of machines now in general use be mentioned in the course of discussing the specific requirements of quality control. Owing to problems of power supply, the stored energy types of machines are coming into widespread use; hence most of the detailed discussion in this paper will allude to such machines.

Most of the opinions and factual data given in this paper are based on tests and analyses made in the Research Laboratory and the production shops of the Lockheed Aircraft Corp.

Definitions of Terms

In order to minimize misunderstandings and ambiguity, several terms will be defined according to the meanings intended for them in this paper.

1. *Quality.*—From the standpoint of structural design of airplanes, interest in spot welding lies chiefly in the strength and consistency[1] of the spot-welded joints, and in the absence of detrimental factors such as cracks, distortion and poor surface condition. Because of this, and also because it is difficult to assign numerical values or demerits to most of the detrimental factors which occur in spot welding, *quality* will be assumed to mean the strength and consistency of the spot-welded joints.

Good consistency is desirable not only to minimize the probability of occurrence of occasional weak welds, but also as an indication that all factors in the spot-weld process are functioning properly. Poor consistency is the first indication of incipient trouble which may later become serious.

2. *Control*, according to Webster, means ". . . to exercise a directing or governing influence, to regulate. . . ." In various branches of industrial activity this word has different meanings. In this paper *control* refers to a total process, including the handling and preparation of the material, operation and maintenance of the equipment, methods of sampling and analyzing of the production output, the use to be made of such analyses and the employment of non-destructive testing and monitoring.

3. *Quality Control* is therefore a total process by means of which satisfactory strength and consistency in spot-welded joints[2] may be achieved.

4. *Statistical Control* (or *Regulation*) refers to a process whereby the output of any machine is sampled at periodic intervals, the results analyzed with reference to previous data and a decision made as to whether current performance is acceptable. Note that the term has a much more limited significance than the broad

* Presented at the Annual Meeting, A.W.S., Chicago, Ill., Oct. 18 to 21, 1943.

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[1] The term "consistency" refers to the uniformity of shear strength of the various welds in a group. It has commonly been expressed in terms of the range between maximum and minimum values but is more accurately represented by the effective deviation from average, as calculated by statistical methods. (See Appendix for detailed explanation.)

[2] See Appendix for discussion of strength and consistency measurements.

term "quality control" previously defined. The latter may include *statistical control* as one of its features.

5. *Standardization* is that process of machine modification and maintenance which makes it possible to (*a*) obtain equal quality of production from any given machine every time it is set up the same way, and (*b*) set up different machines in the same shop to give the same quality of output.

The Basic Requirements of Practical Quality Control

The basic requirements of practical quality control are determined by the nature of the spot weld itself. A spot weld is capable of carrying a heavy load in shear when it is properly made and used, and its low cost and high production rate give it additional value as a design feature in the manufacture of airframes. However, it is completely hidden from view, and its size, shape and other properties are determined by factors that frequently are not under complete control. The result is that although the average strength is easily set at any reasonable value by simple machine adjustment, and although most of the welds in any large group may have strengths fairly close to this average value, occasional ones are produced that are much stronger or much weaker. The very strong ones probably do no harm, but the weak ones may seriously impair the joint, and furthermore may be in violation of the customers' requirements or the assumptions used in structural design. In particular, it is feared by some designers that a weak weld in a compression panel might give way under buckling stresses and start progressive failure.

A number of things might be done to assure maximum weld quality. One would be to modify the machines, material and process so as to yield perfect consistency. The spot-welding machine would be adjusted to make one weld with adequate strength and with all other properties satisfactory. Then all subsequent welds would, of course, be like the first one and perfection would be achieved. But neither science nor industry has discovered how to obtain such ideal consistency.

A second method would be to exert the maximum possible care in selecting the material, preparing the surface and setting up the machine, and then nondestructively test each individual weld for positive assurance of quality and detection of the occasional inferior ones. Unfortunately this method is impossible, for the present at least, because to this date there is no positive non-destructive test method available, in spite of considerable research that has been done along this line.

The method that seems economically feasible and practically possible consists of the following three steps:

(*a*) Standardization of the equipment and process within reasonable limits.
(*b*) Regulation of the setup and use of the spot-welding machines by a method based on statistical predictions.
(*c*) Monitoring of the individual machines, to detect the occasional weak welds whose occurrence cannot be prevented by standardization and regulation.

How to Realize the Basic Requirements

The three basic requirements of quality control will now be explained in the order in which they can most easily be applied to most production shops.

(*A*) *Standardization Requirements*

There are in existence, in nearly every shop, a number of independent variables affecting spot-weld production quality. As these are minimized or eliminated, improved quality is to be expected. One of these is the cut-and-try method used in setting up the spot-welding machines.[3] The use of standardized settings would eliminate this unpredictable variable, would make possible the employment of less highly trained and skilled operators and would permit the operator to use the best possible combination of machine adjustments. This method of operation, however, can be used only after the machines themselves have been standardized and calibrated.

The essential requirements of standardization of spot-welding machines are as follows:

1. All similar machines must be supplied with calibrations of the important features, such as electrode force, stored energy (or, preferably, delivered energy) and forge time delay, so that equivalent welding operations can be obtained at different times and on different machines.

2. Different machines of the same type and model should be modified to have similar performance characteristics, if possible. Attention is called to the fact that absolute equality of calibration is not necessary, but that similarity of performance is desirable and that accurate calibration is essential.

3. Mechanical and electrical maintenance, and perhaps modification, must be supplied so that calibrations will remain nearly constant over a long enough period to make standardized operation economical.

4. In so far as possible, the instruments and relays that are used to control energy, time intervals and electrode force should control these actual quantities, rather than other values that are inaccurate measures of them. For example, the best relay to use to control the energy stored in an electromagnetic type of stored-energy spot-welding machine would be one which responds to actual energy stored, rather than to a current which is presumed to store a certain amount of energy per ampere, but actually does so only when the secondary resistance and primary voltage are correctly fixed.

The details of equipment standardization depend upon the number, types and models of machines in the shop and the test equipment available. The following outline is intended to explain the requirements, rather than how to accomplish them.

1. Material.—Material handling and inspection must be executed with some understanding of the effect of surface condition on weldability. In spot welding, the heat of fusion is supplied by the passage of the welding current through the resistance of the material between the electrodes. A large part of this resistance, in the case of the light alloys, is at the surfaces of the material. The surface preparation process and machine characteristics can compensate for or eliminate the effect of a reasonable variation in surface condition, but they cannot neutralize the effect of the use of the wrong material, or of deep scratches, excessive surface irregularities or poor fit of the parts as they reach the machine.

Therefore, inspection must be maintained to prevent the use of foreign or damaged material. Forming and handling prior to spot welding must be done with sufficient care to permit welding to be satisfactory, and it is the responsibility of the welding department to refuse material which obviously cannot be satisfactorily welded.

2. Surface Preparation.—The methods of surface preparation, if any, can be divided into three general

[3] Some customers or procurement agencies do not permit the use of cut-and-try setups, but others still allow this procedure.

classes: (*a*) removal of dirt and grease by use of cleansing solutions; (*b*) chemical etching; and (*c*) mechanical removal of surface film, such as by scrubbing with metal wool or wire brushing. Selection of the surface preparation method must be made with consideration of the kind of spot-welding equipment and the material being used. Steel requires little if any preparation, while aluminum alloys must be prepared with considerable care. Material to be spot welded in machines in which the amount of energy stored depends partially on the surface condition must be more carefully prepared than if the energy storage were independent of the condition of the material prior to welding.

Thus, no single method of surface preparation can be specified as being the best for application to all shops. It is probably apparent, however, that once a method has been adopted, it should be tested and checked frequently. Successive checks should be made and recorded at shorter intervals than the minimum time usually required for the method to vary seriously from its normal, so that a trend toward unsatisfactory preparation can be corrected before conditions get out of control or parts must be rejected.

Cleaning and etching solutions should be kept at the right concentration and temperature. Available records or experimentation will give the permissible tolerance in the variation of these quantities. The time of immersion should be controlled by a clock or other timing device and, for solutions used at elevated temperature, should be established for each of several temperatures near the optimum, so that allowance may be made correctly for slight variations in temperature caused by loading and unloading the bath.

3. Machine Setup.—The determination of the optimum machine setup depends upon the adjustment, calibration and maintenance of the machines. This is because the making of a good weld requires that both electrical energy and physical pressure be supplied in the right amount and at the right time.[4] A complete or "ideal" machine set-up specification would state (*a*) the energy to be delivered to the weld; (*b*) the current wave shape; (*c*) the electrode force during the formation of the weld; (*d*) the amount of forge time delay used, if any; (*e*) the electrode force during the period of forging; (*f*) the rate of change of force from the welding to the forging values; and (*g*) the size, shape, material and cooling of the electrodes. Because of practical consideration, however, a few of these can be specified directly.

[4] See *Electronic Control of Resistance Welding* by G. M. Chute, McGraw-Hill Book Co., Part III, 318-384 (1943).

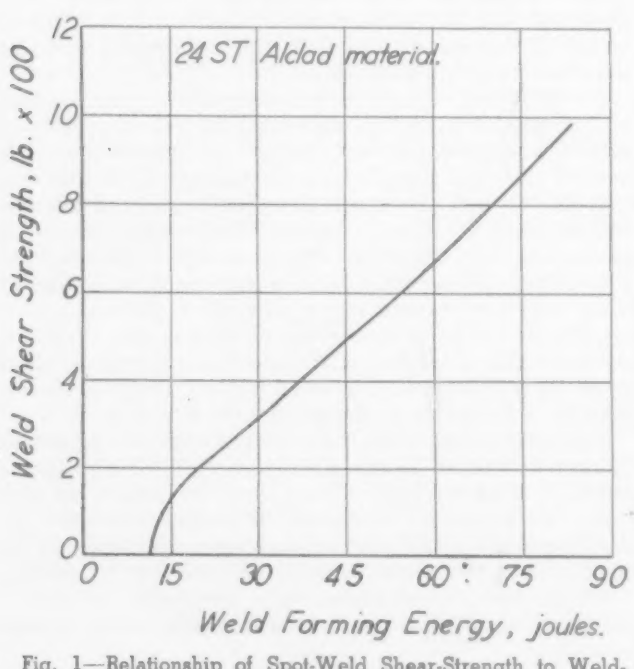


Fig. 1—Relationship of Spot-Weld Shear-Strength to Weld-Forming Energy

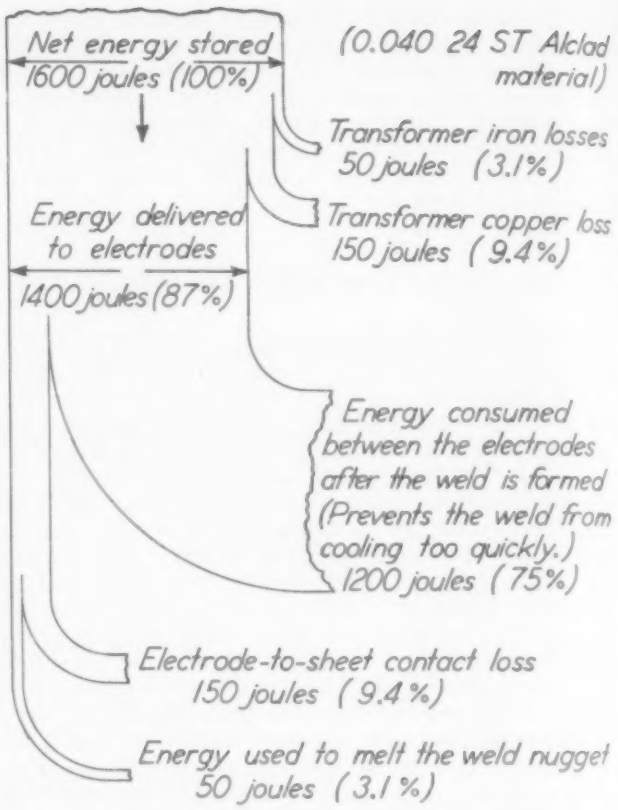

Net energy stored
1600 joules (100%)
(0.040 24 ST Alclad material)
Transformer iron losses
50 joules (3.1%)
Energy delivered to electrodes
Transformer copper loss
150 joules (9.4%)
1400 joules (87%)
Energy consumed between the electrodes after the weld is formed (Prevents the weld from cooling too quickly.)
1200 joules (75%)
Electrode-to-sheet contact loss
150 joules (9.4%)
Energy used to melt the weld nugget
50 joules (3.1%)

Fig. 2—Distribution of Energy Flow in Making a Spot Weld on a Stored Energy Machine

(*a*) *Energy:* The relationship between weld-forming energy and shear strength is shown in Fig. 1. From this it is obvious that high consistency of weld strength requires uniform consumption of energy. There appears to be no means yet available for controlling directly the amount of energy consumed in forming the weld, but it is probably apparent that the first step in obtaining uniform energy consumption is to assure uniform energy storage from weld to weld. A graphical representation of the energy relations in a stored-energy spot-welding machine is shown in Fig. 2. When the magnitude of the weld-forming energy is compared with that of the total energy stored, it is seen that there is little hope of uniformity in the former if the latter be inconsistent.

1. For electromagnetic stored-energy machines, as currently available, the net energy delivered to the weld is less than the stored energy by 30 to 80%, due to the heat loss in the current-interrupting equipment. The energy stored in the transformer up to the instant of discharge depends upon the square of the primary charging current and on the equivalent inductance of the machine, which is determined by the two transformer windings, the core, the external secondary circuit and the impedance of the material between the electrodes. The predominant variables are normally the current, which operates the "current relay," and the resistance between the electrodes, which is highly variable and of appreciable magnitude. The specification of energy for such machines should therefore, theoretically, be given in terms of the surface resistance or preparation, the transformer turn ratio and air gap length, the resistance blocks

used, if any, the setting of the current relay in the primary circuit, the normal delay time between operation of the current relay and actual interruption of the primary current, and the rate of growth of current during this latter interval. Such a specification would be both impractical for shop use and unintelligible to most operators. Certain of these variables can be made nearly constant, or fully dependent on others, so that the energy specification can be simplified. The means of accomplishing this are as follows:

First, the interrupting time of the primary breakers should be adjusted to an optimum value, approximately 0.01 to 0.02 sec., and then carefully maintained at that value within a range of not more than 0.003 sec.

Second, the surface preparation should be standardized and regularly checked as previously described.

Third, the delay in operation of the breakers after tripping of the current relay should be made as short as possible consistent with economical maintenance, say, approximately 0.03 to 0.04 sec., and then rigidly maintained at this value within a range of not more than 0.01 sec.

Fourth, the rate of growth of current should be kept under control by maintaining good voltage regulation at the terminals of the welding machine. This is a matter of selection, maintenance and location of the power supply and rectifier equipment and of adequate bus size and attention to contact voltage drops along the circuit.

Fifth, the resistance blocks for each welding job should be specified directly.

Sixth, variations in equivalent inductance caused by inequalities in number of turns or air gap lengths in the main transformers of different machines might be resolved by the use of calibration charts derived from tests with all other quantities under control as just described. Such a chart, for any one machine, would simply be a two-column tabulation of stored energy and current-relay setting for normal conditions. It would be subject to error due to high-contact resistance between the electrodes, but this is a condition whose seriousness could be reduced to a minimum by careful attention to surface preparation. The current relays, like all other electrical instruments, should be standardized and interchangeable. This is simply a matter of establishing standard air gaps and spring tension, and then maintaining these values on all current relays in the shop by means of periodic check calibrations.

Seventh, the size, shape, material and cooling of the electrodes should be specified directly.

Thus an energy specification for an electromagnetic stored-energy spot welder might have a form similar to the following example:

(*a*) Breaker interrupting time, 0.014 seconds.
(*b*) Breaker delay time, 0.035 seconds.
(*c*) Surface preparation (according to shop standards).
(*d*) D-c line voltage at welder, 130 volts, ± 5 v. max. variation.
(*e*) Resistance blocks, Nos. 5 and 6.
(*f*) Current relay set at value to give 130 joules, as per calibration chart.
(*g*) upper electrode 3/8 in. diam. × 3 in. R., lower electrode 1 in. diam. × 10 in. R.

Of these items, only (*e*), (*f*) and (*g*) would be set by the operator, and they would be in approximate conformity with previously established standard set-up data. The other items would be the responsibility of engineering or maintenance groups.

It should be possible to build a true energy relay which would initiate the interruption of the primary circuit when the stored energy reaches a predetermined value. Until such a device is commercially available, however, the methods described above will probably suffice.

2. For electrostatic stored energy (condenser discharge) machines, nearly all the energy stored is delivered into the welding circuit, but, as in all spot-welding machines, only a small part of this is used in actually forming the weld.[5] The ratio of weld-forming energy to total consumed energy depends largely on the current wave shape, so that if the latter is controlled, as will be described later, equal amounts of weld-forming energy may be obtained by storing uniform amounts in the condenser bank. The amount of energy stored depends upon the capacitance connected and the square of the voltage to which it is charged. It does not depend on the equivalent impedance of the transformer, and is therefore independent of surface condition of the material between the electrodes. The specification of energy for such a machine should therefore be given in terms of the capacity (microfarads) and voltage setup on the machine. Errors in calibration of these two quantities must be kept within reasonable limits. The capacity should be within 5% of the stated value,[6] but since it does not vary from time to time, errors can be compensated for by use of a calibration chart, tabulating stored energy and voltage for each capacitance step provided on the machine. The voltage is usually controlled by manual setting of some standard type of voltage regulator, and checked with a voltmeter mounted on the control panel of the welding machine. Occasional checking with standard test equipment will detect errors in these devices. Recalibration or adjustment should be made when the voltmeter or regulator develops an error in excess of 5% of rated value.

(*b*) *Current Wave Shape:* Both experimental tests and physical theory indicate that the wave shape of the electrode current, especially during the period of current increase, is as important as the amount of total delivered energy in determining the size of the weld nugget. The reason for this is that, for the light metal alloys, the weld ceases to grow at the end of about 0.01 sec. after the welding discharge commences, because at about that instant the rate of heat conduction away from the weld becomes equal to or greater than the rate of heat production by the passage of the current through the weld.

In electromagnetic spot welders, the wave shape of electrode current during the period of increase is determined almost completely by the time-spacing of the opening of the primary circuit breakers, and by the values of resistance shunted across these breakers.[7] It is therefore of utmost importance that the breakers open in the correct total amount of time, in the right sequence, and with the correct time spacings. This probably constitutes the most difficult problem in the maintenance and setup of this type of machine, for it is obviously difficult to maintain the operating speed of each of four or more heavy mechanical contractors to within 0.002 sec. It therefore follows that careful adjustment and maintenance of the breakers is essential. Attention is called to one fact that is frequently overlooked: the breakers must not only open with approximately equal time

[5] Normally less than 5% of the energy delivered to the material between the electrodes is used in melting the weld nugget, the rest of it is dissipated through the sheets, much of it serving to prevent the weld from cooling too quickly.

[6] Manufacturing tolerance is within this value.

[7] The electrical connections and method of operation of the breakers, or contactors, and their shunting resistors are explained in "Scope and Limitations of Stored-Energy Type Spot-Welding Equipment" by G. S. Mikhalapov and C. N. Weygandt, a paper presented at the Annual Meeting of the A.W.S., Cleveland, Ohio, October 1940.

spacings, but the entire time of interruption, from the opening of the first to the opening of the last breaker, must be adjusted to the optimum amount. Failure to observe this precaution may cause spitting, tip pickup, "donut"-shaped nuggets or weak or inconsistent shear strength. The breaker adjustment recommended under the heading of "energy" will be satisfactory for wave shape control during the period that the electrode current is increasing.

Wave shape during the dying or attenuated period is determined solely by the electrical parameters of the secondary circuit—its total resistance and inductance. It is neither likely to change from time to time, nor subject to ready adjustment. If the right resistance blocks are used the wave shape of this part of the circuit may safely be neglected.

The current wave shape in electrostatic machines is determined solely by the electrical parameters of the primary and secondary circuits—the resistances, inductances, coefficient of coupling, the transformer core loss and turn ratio and the amount of capacitance used in storing the energy. Of these factors, the only ones under direct control are the turn ratio and capacitance. For a given amount of energy and capacitance, a higher ratio of primary to secondary turns produces a flatter wave shape of electrode current. For a given energy and turn ration, a greater capacitance will produce a flatter wave shape. If the turn ratio is not adjustable some control of wave shape can be obtained by varying the ratio of voltage to capacitance; for a given energy, the greater the capacitance the less will be the voltage and the flatter will be the wave shape of electrode current.

As in the case of the electromagnetic machines, the current wave shape during the first 0.01 to 0.02 sec. after the start of flow of the welding current is of considerable importance. The machine set-up chart should therefore carry a combination of voltage and capacitance that will give the desired energy, and also a combination of capacitance and turn ratio that will give the optimum sharpness of electrode current wave shape. These values must be determined by careful and thorough test for each size of machine and combination of materials, although this work will probably turn out to be simpler than this outline may make it appear at first.

(*c*) *Electrode Force:* The production of the optimum amount of force at the electrode tips is a purely mechanical problem. The over-all system should be free of friction and inertia effects, the sliding and rolling parts should move freely but without lateral play and the pressure regulator valves should be kept clean and in good repair. Periodic recalibrations will permit the detection of unsatisfactory mechanical conditions and, if posted on the machine, will assist the operator in obtaining the prescribed standard machine setup.

As the weld is formed, the molten metal tends to flow away due to the pressure caused by the electrode, and as the weld cools it contracts. In order to consolidate the weld properly under these conditions, it is necessary that the electrode follow the work with adequate force, and therefore that friction and inertia be kept to an irreducible minimum.

(*d*) *Forge Time Control:* It is common practice, in the spot welding of most of the light alloy sheet materials, to use a variable electrode force during the welding operation. The optimum value of force during the time of weld formation, referred to as the "welding force," is usually too low to assure proper consolidation of the weld nugget and prevent cracking as it cools, and so the force is increased to a larger or "forging" value soon after the welding current starts to flow. The time interval between the beginning of the current discharge and the initiation of the increase in force is called the "forge time delay." If the forging force comes in too late it is of no avail, and cracked welds may be produced. If it is too early, the effective welding force is increased and both weld strength and consistency are reduced. The relationship between forge time delay, strength and consistency for spot welding of 24ST Alclad material based on actual tests is shown in Fig. 3. It is to be noted in this figure that the optimum delay varies with material thickness, but is in the region of from 0.05 to 0.12 sec. for those gages for which data are available.

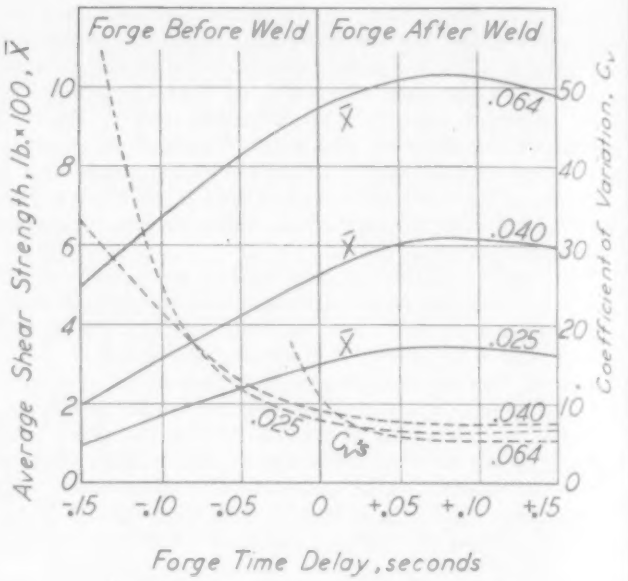
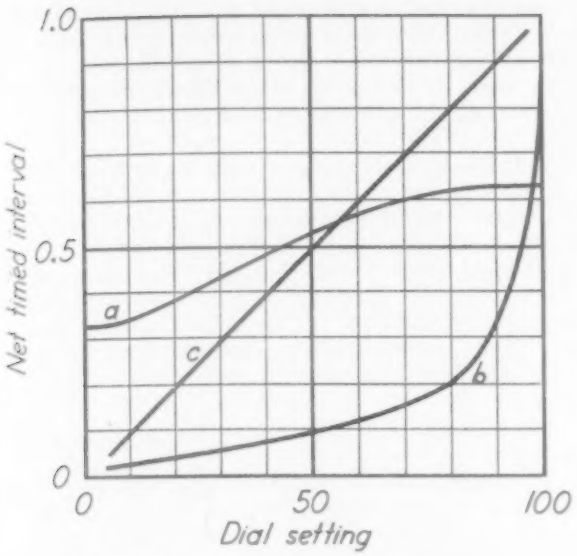


Fig. 3—Effect of Varying the Forge Timing

In some machines the forge time delay is determined by a more or less fortuitous combination of the timing of relays, contactors and valves. Usually the tendency in such machines is for the forging action to come in too early, although a sluggish electrovalve may sometimes make it too late, as well as erratic. Other machines are provided with slightly more positive time control of forging, and some are equipped with accurate electronic time relays. There is probably no time interval in the spot-welding cycle that is so critical as forge time delay. Every machine intended for use in high-quality welding should be equipped with positive control of this feature, preferably by electronic means because of its fast, consistent, positive action. The timing relay should be connected so that it starts its time measurement from the actual weld-current discharge, or some relay or tube that initiates this discharge. It should not be initiated at the commencement of energy storage, because the forge time delay is very small in comparison to the relatively long period of storing up the energy, and it would be impossible to obtain the required accuracy and consistency of timing. As can be seen from Fig. 3, the forge time relay should be adjustable over the range of 0.05 to 0.12 sec., *net* forge delay, including the operating time of the electrovalve and all intermediate relays. Variations in forge time delay of as much as 0.05 sec. can be permitted, but the timer relay, being only a part of the chain of equipment producing the total delay should be consistent within about 0.01 sec. maximum range for a given setting.

(*e*) *Hold Time:* The amount of time throughout which the forging force is held on the electrode is referred to as the "hold time." The magnitude and consistency of this quantity are probably not of great importance, although the total hold time does have some influence on weld quality. If the electrode is raised too soon



Curve (a) has inadequate range
Curve (b) is difficult to reset in the high range
Curve (c) is ideal

Fig. 4—Timer Calibration Curves

it acts as a switch to interrupt the tail of the welding current discharge, causing local heating, tip pickup and short tip life.[8] If the hold time is reduced still further, it may prevent complete forging of the weld, and cracking may occur. If the electrode force is maintained longer than necessary, it will slow down the operation of the machine and impair production.

Thus it is seen that the hold time should be adjusted to the minimum value that will not produce excessive tip pickup, as can be determined experimentally. There are a number of timer relays, some electronic and some mechanical, that are satisfactory for control of this feature. Attention is called to the fact, however, that some timers have been used that had poor calibration curves. Curves such as are shown in Fig. 4 (*a*), or 4 (*b*) are unsatisfactory; an ideal curve is shown in Fig. 4 (*c*).

(*f*) *Off Time and Squeeze Time Before Welding:* These intervals are important only as they affect the speed of production or the ability of the operator to move the work ahead and properly locate the welds. The only attention that need be given to off time is that the control have sufficient range and that it be reasonably consistent so as not to distract the operator. Squeeze time before welding probably serves no useful purpose in spot welding, and may be reduced to the minimum.

(*g*) *Electrode Tips:* The condition of the electrode tips can seriously affect the quality and rate of welding. If the electrode face temperature rises, pickup is increased and the time between cleanings is reduced. Such a condition may be caused by inadequate coolant flow, too high a coolant temperature, dirty material or action of the electrode as a current switch[9] with resultant arcing as it leaves the work although the latter is almost never visible. Skidding of the electrodes, due to excessive deflection of the arms of the machine, may also increase tip pickup.

The shape of the electrode face, as well as the total force, determines the area of contact on the outside of the sheet, and therefore the net unit pressure in the weld metal. It also determines the rate of spread of force through the material being welded, and therefore affects the distribution of resistance, welding current and heat, as well as heat conduction away from the weld area. Thus, improper face shape can be responsible for poor weld shape in plan or section, or for excessive penetration or indentation. Such conditions are usually accompanied by poor consistency of shear strength.

The maintenance of electrode face curvature is a problem deserving serious consideration. The radius of curvature is large compared to the diameter of the face, and the usual tip dressing methods tend to destroy the accuracy of the curvature at least as rapidly as the use of the electrode in welding. Usually the spot-welding operator has neither the training nor the equipment required to reface the electrode tip properly.

One solution to this problem is to change tips at fixed time intervals, or after every certain number of welds have been made. To make this system produce results, the removed electrodes should be checked at some central station, and refaced and refinished, if required, by a trained employee using equipment designed for this purpose. Coincidental to this is the matter of educating the operators to change the electrodes according to schedule, especially where there is much emphasis on producing the maximum number of welds per shift.

Another solution would be to employ a tip-surfacing device as part of the equipment of the spot-welding machine. This would automatically retain the correct shape on the electrode.

(*B*) *Regulation Based on Statistical Methods*

The word *regulation* as used in this paper is synonymous with *statistical control*, and refers to any process, supervisory or inspectional, whereby the continuance of the use of any machine setup depends upon the finding of the most recent sampling of that machine's production.[10]

Statistical control has three prime objectives: (1) to reduce the number of rejections and machine shutdowns due to poor performance; (2) to assist in establishing the optimum specification limits of satisfactory quality; and (3) to provide a reasonably reliable measure of actual production quality. When these objectives are finally achieved, the net production will have been improved because of greater quantity, lower costs and better quality.

The basic principles of statistical control have been thoroughly worked out and are described in numerous references.[11] Briefly these principles are:

1. To select samples of actual production and test them for conformance to specifications.
2. To estimate the probable quality, or conformance, of all production by analysis of the samples.
3. To predict the future quality by considering the trend of past and present quality.

The methods of sampling, of extracting data from the samples and of arriving at a decision as to whether to permit further use of the machine setup that produced the sample constitute the regulatory stystem. There is almost no limit to the number of such systems that could

[8] This applies particularly to the electromagnetic machines, since the attenuation of current in a circuit containing only resistance and inductance cannot be so rapid as one in which capacitance makes critical damping possible. Oscillographic records show that current interruptions at the electrode are frequently as great as 1000 amp.

[9] In electromagnetic machines, see discussion under "Hold Time."

[10] See "Statistical Control," as explained under the heading "Definition of Terms."

[11] Control charts and statistical control methods are discussed in more detail in the following references:

(1) "An Engineers' Manual of Statistical Methods" by L. E. Simon, particularly Appendix C, p. 188.

(2) *A.S.T.M. Manual on Presentation of Data*, 1941 Edition, particularly Supplement B, p. 47.

(3) "Quality Control" by W. A. Bennett and J. W. Rogers, *Aircraft Production*, April 1943, pp. 172–175.

(4) "Statistical Control in the Aircraft Industry" by E. Arthur Pinto, *Aero Digest*, July 1943, p. 313.

(5) "Quality Control in Production Engineering," in *Aircraft Engineering* (*Gr. Britain*), Feb., March and April 1943.

(6) "Control Chart Method of Controlling Quality During Production," American War Standard, April 1942.

be proposed. Each such system would have some mathematical probability of giving adequate regulation, some would be better than others; each would require a particular set of conditions to be maintained in the shop. One might be capable of very accurate regulation, but be too involved or expensive to apply while another might be quick and simple to use, but have such poor probable accuracy of prediction as to be almost useless as a regulatory system. This may be illustrated by the following two fictitious examples:

At one extreme, System No. 1 might require the making of a 100-spot test panel after each setup and at the end of each hour thereafter. Such panels could be cut up into single specimens, pulled in shear and analyzed accurately to determine the average strength and consistency, and perhaps the base strength of the group.[12] These latter figures might then be employed as a guide to the use of the machine. Such a system would have a fairly high probability of accurately measuring the quality of spot-weld production, but it would be so cumbersome and expensive to operate, and would slow down production so much as to be practically impossible to use in any production shop.

At the other extreme, System No. 2 might require the making of a single sample spot weld, pulling this in shear, and observing the strength. If this shear strength exceeded a certain arbitrary minimum value for the material and gage being spot welded, the sample might be accepted as proof of satisfactory spot-weld production. This process might be repeated after each setup, and perhaps once each hour thereafter. (It is assumed in this example that each test sample stands by itself—that no records or charts are maintained.) Such a system would be a poor one, because the probability that the single spot would fairly represent all the welds to be made during the subsequent hour would be very small, and therefore only a low probability of adequate strength could be guaranteed.

These extreme examples lead to the following general statements:

1. Some method of sampling must be used, since destructive testing of all production is obviously not feasible.

2. A statistical control system, based on sampling and analysis, can predict the probable quality of production.

3. The accuracy of prediction depends upon the system used.

4. Small samples taken individually are practically meaningless, but if they are taken periodically and compared with each other and with some established standard they may be of great value. Incidentally, small samples taken frequently probably give a better representation of the quality of production than large samples taken at long intervals.

5. The more the system is expected to do, the more expensive it may be to operate. However, although the examples do not illustrate it, the benefit to be derived from an adequate system usually more than offsets its relatively greater operating cost.

6. Production requirements, shop conditions and the provisions of the process and inspection specifications are likely to affect greatly the type of system to be used.

In connection with the selection of the statistical control system, it is probably obvious that the smaller the number of variables that must be kept under control, and the fewer the charts and records that must be maintained, the faster and more economical will be the functioning of the system. This leads immediately to the conclusion that the various machines in the shop which are used to weld the same or similar materials should themselves be as nearly equal in adjustment and performance as possible.

Thus, although a complicated system could be adopted that would operate over a number of machines with different and varying characteristics, a much more economical system could be used if all the machines were first stabilized and then all the nearly similar machines were standardized before applying the statistical control.

Procedure in Installing a Statistical Control System.—Having first standardized the spot-welding machines, the installation of the statistical control system might be as follows:

(*a*) Obvious faults in the process or equipment should be corrected.

(*b*) The quality of the spot-welding production should be surveyed by obtaining a representative sample, of about 100 spot welds, of the output of each machine. This should first be done on a single gage and material representing the average output of the shop. All machines should be included, and all conditions such as surface preparation, machine setup and operating procedure should be in accordance with the tentative shop standards.

(*c*) The data collected in the shop survey would then be analyzed by some mathematically sound method. Either the average strength or the base strength[12] should be calculated and used as a measure of strength, and the standard deviation[12] or coefficient of variation[12] calculated as a measure of consistency. The range (difference between maximum and minimum strengths) is not an accurate measure of consistency, although for ten or fewer spot welds the standard deviation is probably no better; however, the initial sampling tests should contain at least 50, and preferably 100 or more, spots each.

(*d*) Using the results of the general survey, the next step should be to establish maximum and minimum allowable values of average strength and range for future small samples (five to ten spots) from the same machines. Such allowable values should be derived from a careful analysis of the larger body of 50 or 100 samples taken during the survey, and should be so selected that there is a high degree of probability that if a small sample satisfies the imposed conditions, the entire body of welds will be of about the same strength and consistency as was the case with the body originally surveyed. Tests whose results fall within the limits are then taken as indication that the machines have not changed and that they are therefore still doing acceptable welding. By using nondimensional units this process might be simplified somewhat, and if one standard were adopted for the entire output of the shop, the system might be further simplified, requiring only one set of limits of range and average strength for all machines and gages, and perhaps for all the commoner materials.

(*e*) Control charts[11] similar to that shown in Fig. 5 should then be established, and would afford direct control of the use of the machines. Any machine whose average spotweld shear strength or range falls outside of the limits on the control chart could reasonably be assumed to be operating differently than when first tested. A discrepancy in average strength might perhaps call for the recalibration of some instrument or an adjustment of line voltage or other variables. If the range becomes excessive, it could be assumed that something is not as it should be; perhaps the surface preparation is inadequate, the forging is coming in too early, or electrical troubles are responsible. Practice will quickly

[12] The *base strength* is defined as the average strength of the group less twice the standard deviation. The *standard deviation* is the root mean square of the deviations of all the individual strengths. The *deviation* of any value is the difference between that value and the average of the group. The *coefficient of variation* is 100 times the ratio of the standard deviation to the average. The *range* of any group is the difference between the maximum and minimum values. These terms are further explained and illustrated in the Appendix.

develop the ability to interpret the control chart in terms of maintenance procedure. Experience of one aircraft manufacturer using a quality control system has definitely shown that the machines are always found to have some operating defect in cases where they are shut down due to deviation beyond the control chart limits.

(*f*) Data obtained from hourly or other regular sampling would be plotted immediately and would make possible a long-time and accurate evaluation of output, quality. The number of spots in these samples would of course, be much smaller than in the initial 100-spot test, but they would be taken so frequently as to make possible the drawing of a continuous quality record. The trends of average strength and range from sample to sample on any machine would be employed as an indication of whether trouble is likely to occur, thus making it possible to correct faults before they get so bad as to interfere with production. This is one of the basic objectives of a control system.

(*g*) As the results of the system improve the quality of production, the number of spots taken in each periodic test could be reduced, and the system cost gradually decreased to a minimum.

It should be pointed out, of course, that the outline just given for a statistical control system is not complete, and it is only one of a number of systems that could be used. The important point of this discussion is that some systems based on sound statistical methods be applied as soon as standardization is effected.

Lest the impression be given that statistical methods are bound up in advanced mathematics and deep mystery, attention is called to the fact that the development of the statistical relationship and the numerical values of many of the constants (particularly with reference to the relation of the small sample to the total group of welds) have already been thoroughly worked out and are available in standard books on the subject.[11] Statistical control is a tool to be used where applicable, and its derivation is only of academic interest, much like a precision shop tool which can be used by a machinist without any knowledge of machine design or stress calculations.

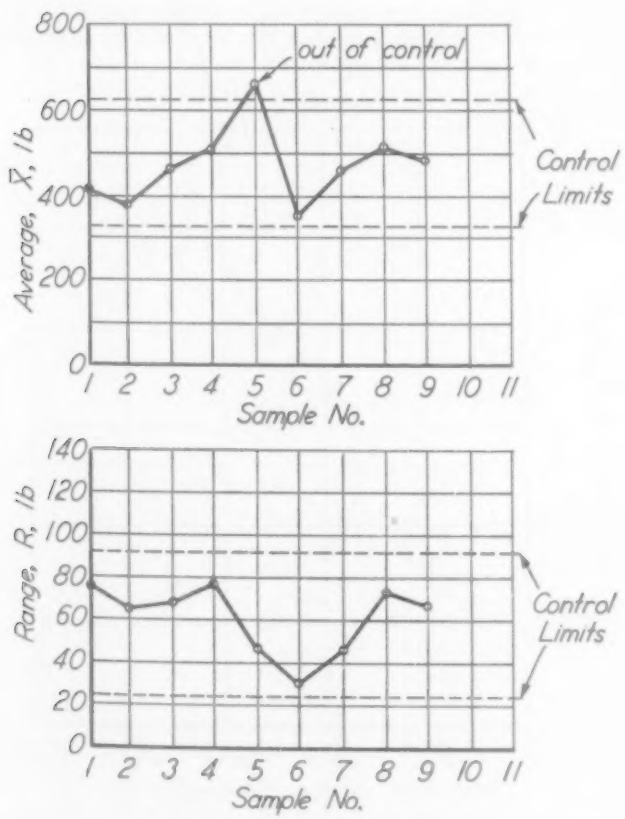


Fig. 5—Sample Control Chart

(*C*) *Monitoring*

The coordinated combination of machine standardization and statistical control, as previously described, would be able to make a prediction of the probable quality of production. It could guarantee that a certain large fraction of the welds would probably have the required strength, but it could not predict when or where the occasional weak one would occur. The fraction of welds that would be satisfactory might be very close to unity; the remaining ones might be (but need not necessarily be) unsatisfactory.

There are, however, numerous joints in airplane construction for which positive assurance is required that each individual joining unit be of adequate strength. Examples of these joints are (1) those which employ only a small number of spot welds, and (2) rows of welds in compression panels subject to buckling loads, where the presence of only one weak weld might initiate progressive failure.

The making of a dangerously weak weld in any such joint could not be tolerated, and therefore until the possibility of this happening is eliminated, it precludes the application of spot welding in the design of such joints.

If some type of device could be used which would measure the strength of each weld as it is made and indicate this to the operator or record it on a chart, the hazard just described could be eliminated. Such a device is called a "Monitor." A spot-weld monitor would indicate either the strength or the strength-classification of a spot weld immediately after its formation, without destruction or impairment of the work, or removing it from the machine.

A number of methods have been tried for determining the shear strength of a spot weld without destructive testing. Those which are based on measurements obtained at the time of welding are referred to as "monitoring," whereas those which are done at some subsequent time, and usually some other place, are called "non-destructive testing." Neither type of strength determination actually measures the shear strength; both measure certain combinations of quantities that are supposed to be an indication of strength, and can be proved only by experimental checking.

Non-destructive test methods have been based on many ideas, some of which are:

1. Measurement of the electrical impedance of the weld at high frequency.
2. Measurement of the response of the welded sheets to very high frequency ("supersonic") sound waves.
3. Approximate determination of weld area by X-ray photography.
4. Measurement of the hardness of the sheet at the center of the electrode impression.
5. Measurement of the diameter of the weld nugget by hardness testing across the electrode impression.
6. Pry test with a screw driver or other tool (not always non-destructive).
7. Measurement of the electrical resistance of the material between the electrodes, either before or after the spot-welding operation.

Probably other methods have been or are being tried. Monitoring methods have also been based on various

principles, all of which are attempts to measure the energy used in making the weld. Examples of methods that have been tried with varying degrees of error are as follows:

1. Measurement of the maximum or average electrode current.
2. Measurement of the total charge (the product of current and time).
3. Measurement of the maximum or average power flow.
4. Measurement of the voltage drop in the secondary circuit.
5. Measurements based on the response of a thermocouple placed in the face of one of the spot-welding electrodes.
6. Measurement of the integral of the product of current squared and time.
7. Measurement of the energy stored, or released to the secondary circuit.
8. Measurement of the energy consumed between the electrodes throughout a certain specific time interval.

Again, probably other methods have been or are being tried.

Among the monitoring methods listed, Nos. 5 and 6 have proved to be of considerable value in the spot welding of steel on a.-c. machines, particularly the thicker gages. Method No. 6 is based on the assumption that the effective resistance is approximately constant—an assumption which is reasonably true for steel but very inaccurate for the light metal alloys. This method measures a quantity proportional to the energy input to the welding machine if the resistance is constant, but does not consider either the time or the space distribution of this energy.[13]

A monitoring device based on the principle outlined in method No. 8 has been built and tested experimentally. It has been found to show excellent correlation between shear strength and instrument response, when monitoring the spot welding of light alloys on stored-energy machines.

This monitoring method is based on the hypothesis that the electrical energy absorbed in melting the weld nugget is a valid indication of the weld shear strength. The reasoning behind this is as follows:

1. The net energy consumed (input less losses) is proportional to the volume of metal melted.

2. The volume of metal melted should be a measure of shear strength of the weld, because (*a*) the volume varies with the area of the weld, since the ratio of thickness to diameter remains nearly constant for a given type of machine and general setup; (*b*) the area of the weld determines its shear strength.[14]

3. Hence a measurement of net energy consumed should be an indication of weld strength.

4. A measurement of energy *input*, carefully restricted to the neighborhood of the weld and the period of its growth, should be related to energy consumed, and hence to weld strength.

The correlation possible with this type of monitoring equipment is shown in Fig. 6.

[13] In the case of the light alloys, the resistance before welding varies over a very wide range from spot to spot on a given sheet, and it also may vary as much as 100 to 1 during the welding operation on any given point. The monitoring method just described is therefore not used for light metal spot welding, because of (1) the resistance variations in time and space, (2) the fact that weld growth ceases at the end of about 0.01 sec. and (3) the fact that the energy input to the machine or secondary circuit is many times greater than that actually consumed in melting the weld (see Fig. 2). A recent investigation of the relationships of spot-weld shear strength to contact resistance is contained in "Second Interim Report of the R-52 Sub-Committee on the Spotwelding of Light Alloys" by Gordon H. Field, H. Sutton and H. E. Dixon, in the *Institute of Welding Quarterly Transactions (Great Britain)* for April 1943, pp. 49–50.

[14] This has been substantiated by recent work in non-destructive weld testing.

Monitoring is not necessarily superior to non-destructive testing except that, first, it is or may soon be available whereas a satisfactory method of non-destructive testing still appears to be a hope for the future; and second, it operates with the welding machine and therefore precludes the necessity for additional stations in the spot-welding or assembly departments for use in non-destructive testing. Either method of measuring the strength classification of every weld would be satisfactory, and whichever is the more reliable and the sooner available should be adopted.

It might at first appear that standardization and statistical control are not necessary if a reliable monitor or non-destructive tester is available, but such is not the case. A monitor, for example, might indicate that a weld, just made, is of insufficient strength, but it could not change the properties of the weld after it is once formed. Thus, without standardization and regulation (or "statistical control") a machine might operate erratically, or be poorly set up, and therefore frequently make weak welds. The most that accurate monitoring or any kind of testing could do to help the situation would be to call attention to the weak welds. The operator might return to or near each weak spot and make a new one, or the part could be rejected altogether, but in this process the cost of spot welding would be greatly increased, and the rate of production correspondingly reduced.

In summing up, the three basic requirements for good quality control in aircraft spot welding are standardization, regulation and monitoring or non-destructive testing. If perfection of machine and material standardization were achieved, neither statistical control nor monitoring would be necessary. But since even the best possible standardization can only be a close approach to perfection, and therefore since at least slight variations are bound to occur, it is obvious that statistical control is essential for the maintenance of high strength and consistency and as a means of fairly measuring the general quality of production, and that monitoring is required for positive proof of the strength of individual spot welds as they are produced.

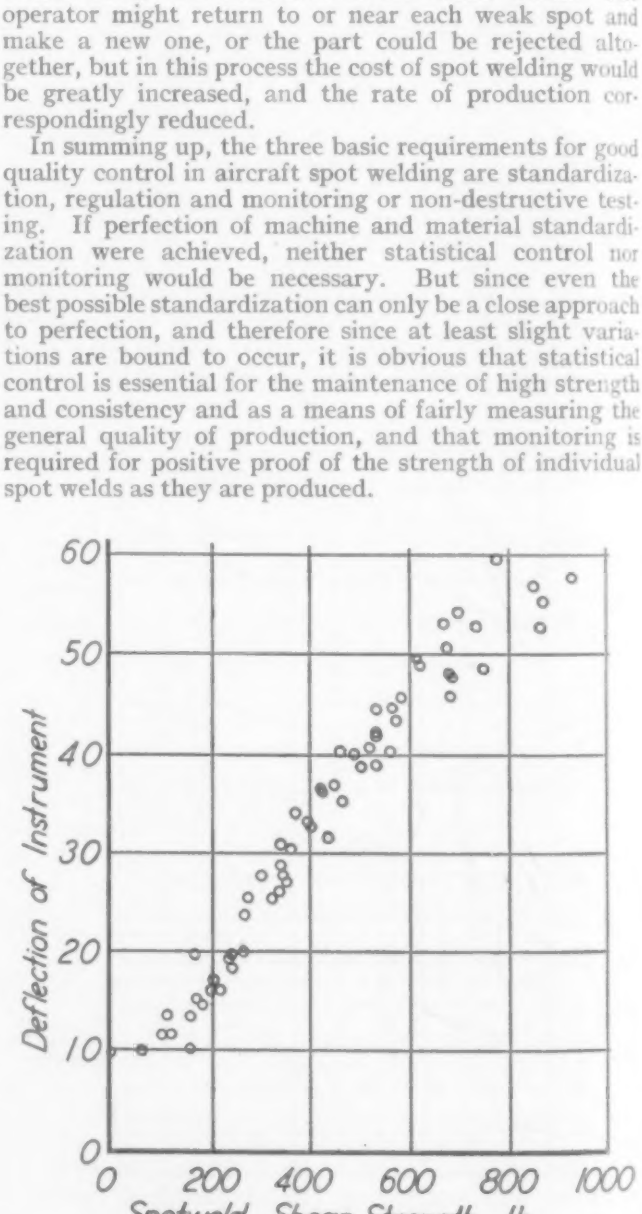


Fig. 6—Correlation Curve of Monitor for Stored Energy Spot Welders

Benefits to Be Derived from Complete Quality Control

The work involved in satisfying the basic requirements of quality control involves some expense, which must be justified. However, in this paper it is probably sufficient simply to list the advantages which an adequate control program will provide.

1. The average strength can be kept very close to the design or contract specification value.

2. A specified fraction of the welds, say, 95% or 99%, can be guaranteed to have shear strengths equal to or greater than the minimum permitted value.

3. Strength consistency can be kept at a maximum, which in itself has a number of advantages:

(*a*) Positive assurance of high consistency permits the use of lower average strength, with resultant saving in energy costs, improved sheet efficiency and the reduced possibility of the occurrence of the other detrimental factors of spot-weld quality.

(*b*) High consistency is the best possible assurance that all factors in the operation of the machine and process are functioning correctly.[15]

(*c*) Continuous high consistency production is excellent proof that shop conditions are under control, and that trouble is neither occurring nor probably impending.[15]

4. The occurrence of detrimental quality factors, such as cracking or poor surface condition, can be almost completely eliminated, if the control charts are based on original setups that produced satisfactory welding.

5. The number of weak spots can be reduced to a minimum, their locations can be positively indicated and definite steps can be taken to compensate for them or correct them.

With the realization of these benefits, spot welding can confidently be used for applications such as structural parts now prohibited or viewed with skepticism by designers. This wider use can be expected to lead to higher production rates and lower assembly costs. There are also other specialized advantages, such as in attaching the skins of supercharged cabins, wherein spot welding has a distinct advantage in terms of the decreased number of potential air leaks and in a smoother exterior surface being presented to the slip stream.

From the foregoing analysis, it seems that the cost of operating a good quality control system should be far exceeded by the value of the benefits to be derived.

APPENDIX

Statistical Measures of Spot-Weld Quality

The practical numerical measures of spot-weld quality are (1) the strength of the spot-welded joint, and (2) the consistency of individual spot-weld shear strengths. These qualities are usually calculated from the tabulated shear strengths of a number of individual spot welds cut out of panels that were welded together on the machine in question. There are, however, a number of different ways that the test data can be handled, and therefore there are different ways to state or "measure" the strength and consistency of the group. This appendix is intended to review the more common quantities used in these methods of analysis, and to explain their significance.

[15] In other words, if all factors and conditions are correct, consistent operation can be attained; departure from consistent operation is the first indication of incipient trouble which may later become serious.

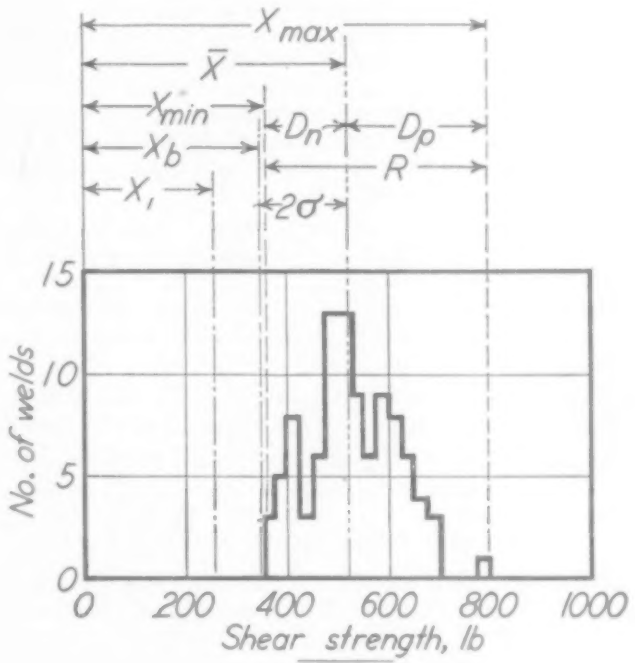
Strength

(*a*) Probably the most obvious representation of strength is the average of the group. This is usually symbolized by the letter $\bar{X}$, and is shown in the typical "frequency chart" or "histogram" of Fig. 7. The average strength may sometimes be misleading for two reasons: (1) it may be the same for a widely distributed group as for a perfectly consistent group, and (2) it is not necessary that half of the welds, or any particular fraction, be as strong as the average. For example, the average of the following four values, 200, 200, 200 and 600 lb., is 300 lb. and yet three out of four of these values are 33$^1/_3$% smaller than the average.

(*b*) In order to overcome these difficulties, an alternate method is used, in which the strength figure is a function of the average strength and also of the dispersion, or inconsistency, of the group. Although this method of strength representation is not universally used, and may seem slightly cumbersome, it has the advantage of giving a more reliable statement of the load that the joint, or any part of it, can be guaranteed to carry. This measure is called the "base strength," is defined as the average less twice the standard deviation,[16] and represents the shear strength that is equaled or exceeded by at least 95% of the welds.[17] A statement of base strength, X_b, is therefore a representation of the load that 95% of the welds can be relied upon to carry regardless of the average strength or the inconsistency of the group.

[16] See the discussion under "Consistency" for description of this quantity.

[17] The figure 95% is a conservative one based on actual tests of production welding, and is less optimistic than the theoretical value for a normal (unskewed) dispersion. If the base strength were obtained by subtracting three, instead of two, times the standard deviation from the average, the fraction of weld strengths exceeding it would be over 99%.



X_{max} = 775 lb		D_p = 252 lb	
X_{min} = 365 lb		D_n = 158 lb	
n = 97 welds		R = 410 lb	
$\bar{X}$ = 523 lb		F_a = 2.04	
X_b = 342 lb		F_b = 1.33	
σ = 91 lb		C_v = 17.4	
X_1 = 257 lb		D_f = 35.3	

Fig. 7—Typical Histogram of a Spot-Weld Test

(*c*) Both the average strength and the base strength must be expressed in dimensional strength units, and therefore they cannot be compared between different materials or thicknesses of material. By dividing the average or base strength by the specification minimum, at present the minimum permitted by the Army Air Corps, non-dimensional quantities are derived. These are referred to as the "average strength factor," F_a, and the "base strength factor," F_b, respectively, and afford a means of direct comparison of all spot-weld tests, regardless of material composition or thickness.

Consistency

This term is usually intended to refer to the uniformity of strengths of the group. Its exact definition depends upon how it is measured.

(*a*) The most elementary representation of consistency is probably the difference between the highest and lowest individual strength values of the group (see Fig. 7). This is called the "range." It is not a reliable figure because it does not take into account the general dispersion of the group; it may depend upon a single chance value. For example, the ranges of the following two groups of figures are equal, although the second group is unquestionably more consistent than the first one from a practical standpoint:

Group 1: 10, 11, 11, 11, 14,14,16, 19, 20; range 10
Group 2: 10, 20, 20, 20, 20, 20, 20, 20, 20; range 10

(*b*) An alternate method, similar to the range but more representative of the dispersion, is the use of the "maximum deviations." The difference between any individual shear strength and the average of the group is called the "deviation" of that shear strength. By stating the deviations of the highest and lowest values in the group a better measure is afforded of consistency than the range alone, but it has two disadvantages: (1) it considers only two chance, extreme values, and (2) it requires the statement and appreciation of two numbers instead of one. This is brought out by considering the following two groups, in which, again, the second is actually the more consistent:

Group 3: 10, 10, 10, 10, 19, 20, 20, 21; max. deviations are $D_p = 21 - 15 = 6$, $D_n = 15 - 10 = 5$
Group 4: 10, 14, 15, 15, 15, 15, 15, 21; max. deviations are $D_p = 21 - 15 = 6$, $D_n = 15 - 10 = 5$

or by comparing the following two groups, in which the second is the more consistent from a practical standpoint.

Group 5: 10, 10, 10, 10, 20, 20, 20, 20; range 10, max. deviations are $D_p = 5$, $D_n = 5$
Group 6: 10, 20, 20, 20, 20, 20, 20, 20; range 10, max. deviations are $D_p = 1.2$, $D_n = 8.8$

Obviously, the dispersions of the above examples were specially chosen, and probably would not frequently occur in actual welding. If two unequally but uniformly distributed groups were compared, either the range R, or the maximum positive and negative deviations, D_p and D_n, would give them fairly good relative ratings. This is shown in the following two uniformly distributed groups.

Group 7: 8, 10, 12, 14, 16, 18, 20; $\overline{X} = 14$, $R = 12$, $D_p = 6$, $D_n = 6$
Group 8: 11, 12, 13, 14, 15, 16, 17; $\overline{X} = 14$, $R = 6$, $D_p = 3$, $D_n = 3$

(*c*) In order to overcome the disadvantages of using the range and maximum deviations, a method may be used which takes into account the strength, or inconsistency of each individual weld. This is done by combining into a single figure the deviations of all individual values. If the deviations were simply averaged, two disadvantages would occur: (1) the positive deviations would cancel the negative ones, and (2) the larger ones which are the ones that impair the total quality the most would not be given sufficient weight. The deviations are therefore combined by extracting their "effective" or root mean square value. The resultant figure, called the "standard deviation" of the group, is thus calculated as the square root of the average of the squares of the individual deviations, or as the square root of the difference between the average square and the square of the average of individual strength values. This is shown algebraically as follows:

Let x = individual shear strength of any weld
$\overline{X}$ = average of all values of x
d = numerical value of $\overline{X} - x$
σ = standard deviation
n = the number of welds in the group

Then

$$\sigma = \sqrt{\frac{\Sigma d^2}{n}} = \sqrt{\frac{\Sigma(\overline{X} - x)^2}{n}} \text{ or } = \sqrt{\frac{\Sigma x^2 - X^2}{n}}$$

(*d*) In order to represent the consistency in comparison to the general magnitude of the quantity being measured, and to use the standard deviation without specific units being attached, the latter quantity can be divided by the average strength of the group. The quantity thus derived, when multiplied by 100, is called the "Coefficient of Variation," C_v, is a non-dimensional unit of consistency which takes into account all of the individual strengths of the group, and makes possible the comparison of consistencies in groups of welds in different materials or different thicknesses of material. The relationships of the standard deviation to the coefficient of variation is shown in the following example.

Group 9: 8, 10, 12; $\overline{X} = 10$, $\sigma = 1.63$, $C_v = 16.3$
Group 10: 18, 20, 22; $\overline{X} = 20$, $\sigma = 1.63$, $C_v = 8.15$
Group 11: 16, 20, 24; $\overline{X} = 20$, $\sigma = 3.26$, $C_v = 16.3$

In this example, the second group has the same total dispersion as the first, and therefore the same value of σ. However, it is generally twice as great and therefore relatively only half as inconsistent, and its coefficient of variation is half as great as that of the first group. The third group has twice as great a dispersion as the first, but, being twice as high in values generally it has the same relative inconsistency, and its coefficient of variation is seen to be equal to that of the first group.

(*e*) Sometimes there is a need for expressing the absolute consistency of a group of spot welds by use of non-dimensional units so that tests on different materials or thicknesses of material may be compared. The standard deviation, σ, is a measure of the absolute consistency, but is not dimensionless; while the coefficient of variation, C_v, is dimensionless, but measures the consistency relative to the average strength of the group, which itself may be a variable for any gage under consideration. Neither of these quantities is therefore suitable for the purpose. When such a requirement arises, however, the answer can be expressed by the "deviation factor," D_f, which is simply 100 times the ratio of the standard deviation to the specification minimum for the material and thickness welded. This expresses the consistency as a percentage of a fixed reference value for the gage and material, and is illustrated in the following example:

Assume the specification minimum to be $X_1 = 6$, then
Group 12: 8, 10, 12; $\bar{X} = 10$, $\sigma = 1.63$, $D_f = 27.2$
Group 13: 18, 20, 22; $\bar{X} = 20$, $\sigma = 1.63$, $D_f = 27.2$
Group 14: 16, 20, 24; $\bar{X} = 20$, $\sigma = 3.26$, $D_f = 54.3$

Comparison of Statistical Parameters

Both the coefficient of variation, C_v, and the deviation factor, D_f, are derived from the standard deviation, σ, and both of them are dimensionless. However, they express the consistency of the group in different ways; each is better for certain purposes. In order to eliminate confusion between these two quantities, their differences are illustrated as follows. Assume three groups of welds in 0.040 24ST Alclad material, for which the specification minimum, $X_1 = 345$ lb.

Group A has average strength $\bar{X}_a = 400$ lb., and $\sigma_a = 40$ lb.
Group B has average strength $\bar{X}_b = 500$ lb., and $\sigma_b = 40$ lb.
Group C has average strength $\bar{X}_c = 500$ lb., and $\sigma_c = 50$ lb.

Groups A and B have the same absolute consistency or spread, as is shown by their equal values of σ, while Group C has a wider spread. This is expressed nondimensionally by their deviation factors, which are:

$$\text{Group A: } D_{f_a} = \frac{40}{345} \times 100 = 11.6$$

$$\text{Group B: } D_{f_b} = \frac{40}{345} \times 100 = 11.6$$

$$\text{Group C: } D_{f_c} = \frac{50}{345} \times 100 = 14.5$$

On the other hand, the consistencies of Groups A and C are the same relative to their respective average strengths, and on this same basis Group B has relatively better consistency. This is shown by their coefficients of variation, which are:

$$\text{Group A: } C_{v_a} = \frac{40}{400} \times 100 = 10$$

$$\text{Group B: } C_{v_b} = \frac{40}{500} \times 100 = 8$$

$$\text{Group C: } C_{v_c} = \frac{50}{500} \times 100 = 10$$

These quantities (C_v and D_f) express the consistency in different ways, and the choice of which to use depends upon the use to be made of the final figure. If, for the purpose at hand, it is considered that a group of welds with high average strength and wide dispersion has as good consistency as another group with lower average strength and proportionally narrower dispersion, then the coefficient of variation should be used, since it gives credit to the first group for its higher strength. On the other hand, if it is necessary to compare the actual total dispersions of two groups, regardless of their average strengths, then their deviation factors should be used, since it may be assumed that the specification minimum, X_1, varies in some rational manner and in smooth progression with the various materials and gages.

Finally, the measures of strength and consistency may be compared as follows:

The average strength, $\bar{X}$, measures strength without giving credit for good consistency, whereas the base strength, X_b, is a strength measure which is made more favorable by higher consistency. Similarly, the deviation factor, D_f, measures consistency without giving credit for high average strength, whereas the coefficient of variation, C_v, is a consistency measure which appreciates high strength levels.

Summary

The statistical measures of spot-weld quality are summed up in the table below.

Some of the algebraic relationships between these quantities are expressed by the following equation:

$$D_f = C_v F_a = 50(F_a - F_b) = 50\,\frac{C_v F_b}{50 - C_v} = \frac{\sigma}{\bar{X}_1} \cdot 100$$

Measured Quality	Measure Used	Symbol	Algebraic Definition
Strength	Average strength	$\bar{X}$	$\bar{X} = \frac{\Sigma x}{n}$
	Average strength factor	F_a	$F_a = \frac{\bar{X}}{X_1}$
	Base strength	X_b	$X_b = \bar{X} - 2\sigma$
	Base strength factor	F_b	$F_b = \frac{X_b}{X_1} = \frac{\bar{X} - 2\sigma}{X_1}$
Consistency	Range	R	$R = x_{max.} - x_{min.}$
	Maximum deviations	D_p, D_n	$D_p = x_{max.} - \bar{X}$ $D_n = \bar{X} - x_{min.}$
	Standard deviation	σ	$\sigma = \sqrt{\frac{\Sigma(\bar{X} - x)^2}{n}}$
	Coefficient of variation	C_v	$C_v = \frac{\sigma}{\bar{X}} \cdot 100$
	Deviation factor	D_f	$D_f = \frac{\sigma}{\bar{X}_1} \cdot 100$

THE SEARCH THAT NEVER ENDS

IN THE industrial life of America, research has been of constantly increasing importance. And today it is a national resource, for the research of industrial and college laboratories is proving its value in War.

To the Bell System, research is an old idea, for the telephone itself was born in a laboratory. Behind its invention, sixty-nine years ago, were researches in electricity and acoustics and in speech and hearing.

And, ever since, there has been a laboratory where scientists have searched to know more about these subjects; and with their associated engineers have applied the new knowledge, fitting it with all the old, to make the telephone better and better.

Their fields of inquiry have broadened and deepened through these years; they inquire into all the sciences and engineering arts which have any promise of improving the telephone. Much has been learned but still more will be, because their search goes on. That is why the telephone laboratory grew to be Bell Telephone Laboratories, Incorporated, the largest industrial laboratory in the world. And it exists to improve telephone service.

Improvements in industry can be left to chance in the hope that some one, sometime, will think of something useful; that some good invention will turn up.

The other way to make improvements is to organize so that new knowledge shall always be coming from researches in the fundamental sciences and engineering arts on which the business is based. From that steady stream will arise inventions and new methods, new materials and improved products.

This is the way of Bell Laboratories. Its search will never end. And as fast as it can the Laboratories will apply its new knowledge practically to the design of equipment and communication systems.

At present—and this started before Pearl Harbor—its trained scientists and engineers and all their skilled associates are concentrating on products of importance to our armed forces. But when this work is happily over they will be ready to continue their developments for the needs of peace.

BELL TELEPHONE SYSTEM

"Research is an effort of the mind to comprehend relationships no one has previously known; and it is practical as well as theoretical." . . . . . *BELL TELEPHONE LABORATORIES*

THE AMERICAN WELDING SOCIETY

ACTIVITIES — RELATED EVENTS

SECTION OFFICERS CONFERENCE MEETING

Twenty-one Sections were represented at the Section Officers Conference in Chicago during the recent Annual Meeting of the SOCIETY, some having as many as three representatives, while one had four present. As intended, the Conference provided opportunity for the Section Officers to get well acquainted with National Officers and other Section Officers, to iron out their difficulties and to express their viewpoints on new matters presented to them.

As recommended, steps are being taken to put into effect as rapidly as possible by-law amendment recently adopted, which provides for seven geographical Districts. The purpose of this amendment is to enable the District Vice-Presidents to properly service the Sections in their Districts. They have been unable to do so heretofore because of the large territory to be covered. Inasmuch as only five District Vice-Presidents were elected for the current year, some territorial adjustments are necessary and two additional District Vice-Presidents have to be elected. Mr. C. H. Jennings was appointed Chairman of this Committee at the Directors' meeting held in Chicago. Matters that will require early consideration by the Committee include: (1) clarification of the classification of membership known as "Sustaining Company"; and (2) establishment of Section boundaries.

One idea for bringing about closer relationship between the National Body and its Sections was the recommendation that means be provided to enable the District Vice-Presidents to pay an annual visit to the Sections in their Districts, and further, to enable the other National Officers to pay more frequent visits to the Sections.

The Membership Committee Chairman stressed the importance of the Sections concentrating on good meetings, with competent speakers, as a means of getting new members and retaining member interest. He suggested that the Sections, through survey, find out the subjects of greatest interest to their members and then make a special effort to get the best talent available. It was generally believed that a dinner, preceding the meeting, promotes a spirit of good fellowship. A non-technical coffee talk adds to the attractiveness of the dinner. Before the technical talk at the meeting, a motion picture on a subject of general interest, or a half hour devoted to a question and answer period, with experts on hand to answer the questions, creates considerable interest. Attractive announcements, distributed widely, well in advance of the meeting, have been found to improve the attendance. Identification badges, sometimes of two different colors, are used to get members acquainted and to learn who are potential members. Joint sessions with branches of other technical societies especially interested in the subject to be presented are often found to bring in new interest. Welding panels arranged in cooperation with the WPB for the benefit of those engaged in war production have added to the prestige of the SOCIETY. Occasional social affairs have created good fellowship and a friendly welcome to the new comer should never be overlooked.

The Membership Committee Chairman also urged all Sections to hold their annual elections in the spring of the year so that the officers can be installed and the season's programs organized under the new regime well in advance of the opening of the fall season and the Annual Meeting of the National Society.

THE OXY-ACETYLENE HANDBOOK

The Oxy-Acetylene Handbook published by The Linde Air Products Co., has been planned to be a basic handbook or manual on oxyacetylene welding and cutting and their related processes. It has been planned specifically to be of use in colleges, vocational schools and secondary schools, and in other teaching institutions having courses in welding, construction methods, shop and other vocational and technical subjects.

The book will also be of interest to those in industrial plants who are responsible for the training of welding and cutting operators. It will be of use to plant management people, engineers, designers, superintendents, foremen and operators in shops where the oxyacetylene processes are or might be used as production or maintenance tools. Price $1.50. Copies available through the AMERICAN WELDING SOCIETY.

MOISSEIFF MEMORIAL COMMITTEE FORMED

Plaque, Street Naming and Symposiums Planned

Associates of the late Leon S. Moisseiff, member of this Society, are forming a memorial committee in his honor to perpetuate his personal and professional ideals. Moisseiff was known as an indefatigable committee member in technical societies, including the A.S.C.E., American Welding Society, A.S.T.M., American Institute of Steel Construction and other groups. He was the first to apply the deflection theory in the design of suspension bridges in this country, having applied it in the design of the Manhattan Bridge. The memorial contemplated would consist of erecting an appropriate bronze plaque at the Manhattan approach to that bridge, and naming this approach "Moisseiff Plaza." In addition, annual symposiums on topics in which Moisseiff was interested are contemplated. A small fund for this purpose is proposed to be secured. Members and friends who wish to serve on the Committee, which involves no personal obligation, are requested to write

The Leon S. Moisseiff Memorial Committee
393 Central Park West, Box 402,
New York 25, N. Y.

The Committee is not accepting any funds at the present time.

$600 CASH PRIZES AWARDED IN METALLIZING CONTEST

Cash prizes have just been awarded by Metallizing Engineering Co., Inc., Long Island City, N. Y., in the first of its new series of Conservation Contests. Open to users of any type metal spraying equipment, these contests are intended to show manufacturers and others how they can save critical metals and time in production and maintenance.

First Prize of $200 was awarded to R. C. Overstreet, Tinnerman Products, Inc., Cleveland, Ohio, for his description of a faster, more durable way to protect Speed Nuts against corrosion. Second Prize, $100 in cash, went to L. W. Sagle, Baltimore & Ohio Railroad Co., Baltimore, Md., for procedures showing how replacements are avoided and worn parts reclaimed quickly and cheaply.

For the economies afforded in building up an undersize rudder stock for a dredge, $50 was awarded to J. S. Kernachan, United States Engineer Office, Buffalo, N. Y. A similar prize was given to C. G. Holloway, Isaacson Iron Works, Seattle, Wash., for a method of salvaging discarded press rams.

Two production applications of the metallizing process rated a $50 prize. One to G. H. Wolfe, M & R Products, Inc., Kalamazoo, Mich., who described how metallized cast iron replaces nickel-chrome steel in the Gasogene unit. The other, submitted by C. Smith of International Telephone & Telegraph Corp., New York, N. Y., told how copper and zinc coatings on steel are replacing solid aluminum for radio transmitter frames.

Twenty-five dollars was awarded to G. De Sylvester, General Electric Co., Schenectady, N. Y., for a method of applying sprayed aluminum on steel magnet inserts. Two Canadian entries each won $25 for wartime maintenance short-

cuts. These were: P. Ziegler, Zapfe Machine Shop, Kitchener, Ont. (repair of axle for road grader), and C. P. Fessant, Motor Vessel Kenozha, Sarnia, Ont. (repair of marine crankshaft).

A special prize of $25 went to T. Horn, Crescent Operations, Anniston, Ala., for information showing how an old bus engine was converted into an auxiliary air compressor used in the operation of this company's metallizing equipment.

EYE SAFETY

To assist in the current campaign against industrial eye accidents, American Optical Co. of Southbridge, Mass., announces it is now making available to industry the following free AO safety promotion services:

1. Safety posters dramatizing the importance of wearing safety goggles on eye-hazardous jobs.
2. A miniature newspaper—*The Safety Clipper*—published periodically and containing material on eye safety designed for reproduction in employee magazines or newspapers.
3. Analyses of plant eye hazards, and recommendations by trained AO safety representatives for effective eye protection programs.
4. A 16-mm. sound training film titled "Right on the Nose" and demonstrating the simplest, quickest methods of fitting nonprescription safety goggles so that workers can wear them in comfort. Also available is a booklet bearing the same title and providing in printed form the information contained in the film.

CHICAGO BRIDGE BECOMES LEAD YARD

The Chicago Bridge & Iron Co.'s Seneca, Ill., shipyard has been made the "lead yard" in the U. S. Navy's new LST construction program. Gibbs and Cox, Inc., Marine Architects of New York, have been retained to make plans and issue purchase orders for all yards building LST's.

The Chicago Bridge & Iron Co. has received contracts from the Navy to build 150% more LST's at Seneca than they built under the first program, which is being completed at the present time, approximately three weeks ahead of schedule.

LST'S are being launched at the Seneca yard at the rate of one a week. Under the new program, completion will be stepped up even faster. The ships built at this yard are 98% complete when launched. The engines are installed, all equipment is in and all piping and wiring ready for the operation of the ship.

ARMY-NAVY "E" AWARD

Fitzgibbons Boiler Company, Inc., won the Army-Navy "E" award. This is an especially outstanding achievement in the case of the Fitzgibbons plant, which had to completely convert its facilities from steel boilers and conditioners to types of war production bearing very slight relationship to the former products. It is a far cry from the building of steel boilers to the making of huge "General Sherman" tanks, the fabricating of armor plate gun shields and platforms, etc. Much new equipment had to be built and installed, delays circumvented, workers trained. In spite of all the handicaps accompanying this internal revolution, the plant has reached production goals deemed worthy of special commendation by the U. S. Government.

PACKAGING STANDARDS FOR OVERSEAS SHIPMENT

Standard packages for delivering steel mill products overseas in first-class condition under even the most severe conditions of wartime transportation have been designed by packaging experts of the steel industry.

Culminating an intensive, three-year study of methods of preparing steel products for overseas shipment in wartime, a fully illustrated, 180-page manual, "Packaging, Marking and Loading Methods for Steel Products for Overseas Shipment," has just been issued by the Committee on Packaging, Loading and Shipping Problems of the American Iron and Steel Institute.

The manual contains instructions which have been approved by the Army Service Forces, the Navy Department and the U.

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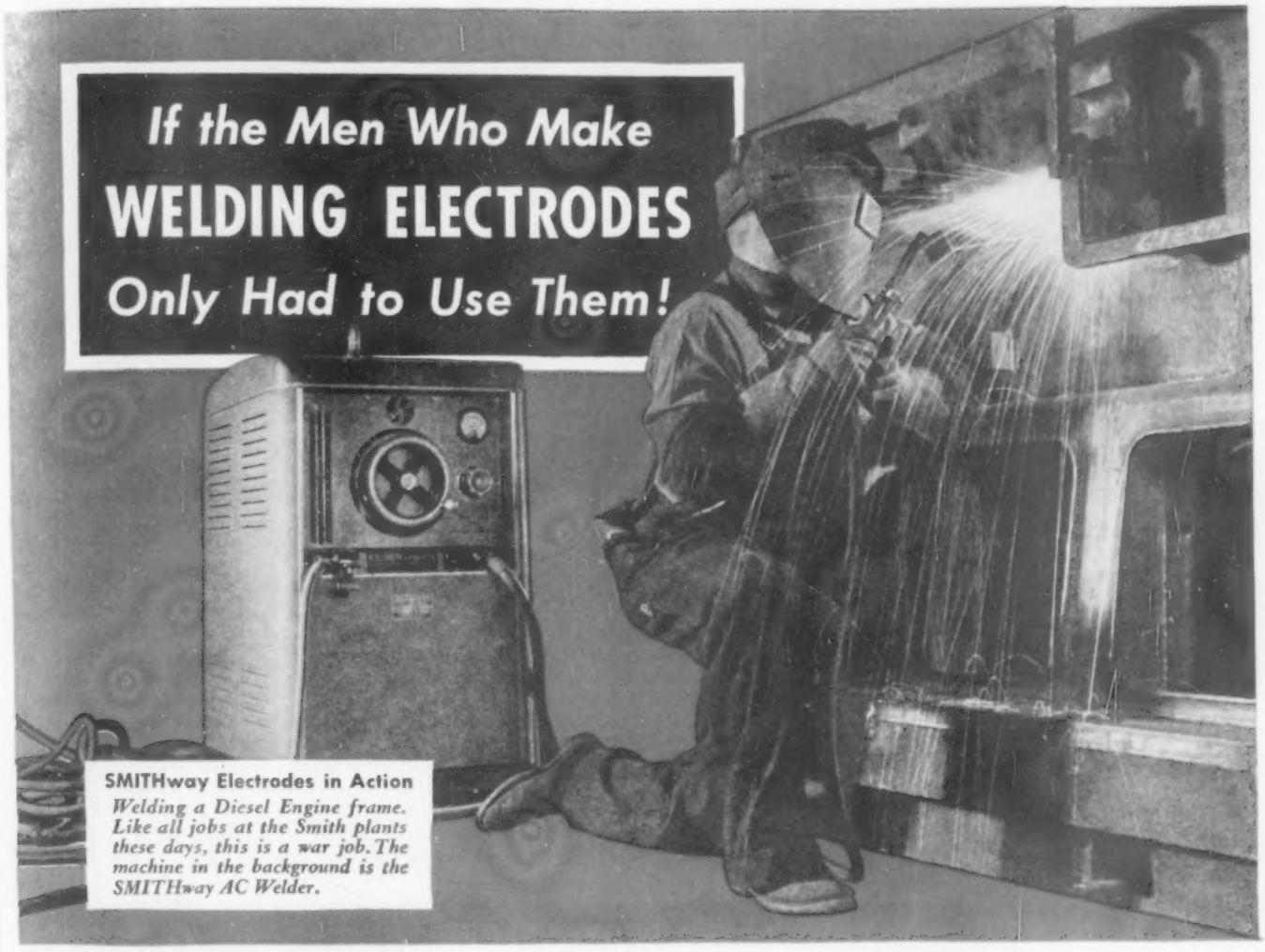

If the Men Who Make
WELDING ELECTRODES
Only Had to Use Them!
SMITHway Electrodes in Action
Welding a Diesel Engine frame. Like all jobs at the Smith plants these days, this is a war job. The machine in the background is the SMITHway AC Welder.

IF the men who make welding electrodes only had to use them—many of your shop problems would cease to be!

Why? *Because welding electrodes are production tools!* To build a good production tool, a man must *know* the problems of using that tool. We make the SMITHway Certified Welding Electrodes that we offer you. They are the same electrodes we use in our shops. SMITHway electrodes, therefore, are *shop tested* in one of the world's largest welding plants . . . where thousands of pounds of electrodes are used every day . . . where *all kinds of welding* is done on a big production scale.

When we tell you that SMITHway Certified Welding electrodes will give you *better welding results* at lower costs, we are stating a *fact* that can be demonstrated in *your* plants.

Mild Steel...High Tensile...and Stainless Steel
WELDING ELECTRODES
made by welders . . . for welders

***SMITHway Welding Monitor** cuts the time of training welders as much as 33⅓%!*

***SMITHway AC Welding Machines** reduce spatter, completely eliminate "arc blow."*

A. O. SMITH Corporation
MILWAUKEE · WISCONSIN · HOUSTON · TEXAS
OFFICES AT NEW YORK, PITTSBURGH, CHICAGO, TULSA, HOUSTON, LOS ANGELES, SEATTLE

U. S. Treasury Procurement Division, for wrapping, tying, boxing, marking and loading various steel products. In preparing the instructions, many consultations were held with purchasing missions representing the British Empire, China, U.S.S.R., the Fighting French, Belgium, the Netherlands, Iceland and Turkey.

PYROPHYLLITE

An interesting, attractive booklet on the properties of various types of pyrophyllite has been issued by R. T. Vanderbilt Co., Inc., 230 Park Ave., New York 17, N. Y. Its uses, including welding and coatings, is also described.

EUTECTIC DATA BOOK

Eutectic Welding Alloys Company, 40 Worth St., New York, N. Y., manufacturers of Castolin Eutectic welding alloys and fluxes for low-temperature welding and brazing, have issued a new Data Book which contains the latest information pertaining to Eutectic low-temperature welding. Copy available on request.

J. R. HENRY PROMOTED

J. Robert Henry has been appointed to the position of Welding Engineer for The Cleveland Diesel Engine Division of The General Motors Corp. at Cleveland, Ohio. Mr. Henry is an old employee of the corporation, having worked at the Winton Engine Co. (now Cleveland Diesel Division) and The Electro-Motive Division at La-Grange, Ill. Since 1935 Mr. Henry has been associated with sub-contractors of Diesel engine weldments for the Cleveland Diesel Division. He worked as factory representative at Lukenweld, Inc., at Coatesville, Pa. In 1938 he joined the Clearing Machine Corp. as welding engineer and supervised the welding design and construction of Diesel engine frames. In 1942 he helped organize the Warren City Tank and Boiler Co. as the Warren Fabricating Division of the Taylor Winfield Corp.

In his new capacity Mr. Henry will aid the design engineering group in the creation of new fabricated products and will supervise the fabricating procedure of Cleveland Diesel sub-contractors.

THEISINGER PROMOTED

William G. Theisinger, who has been Director of Welding Research at Lukens Steel Co., Coatesville, Pa., since February 1941, has been appointed Assistant to Vice-President, it was announced recently by D. S. Wolcott, Vice-President of the company. Dr. Theisinger will assist Mr. Wolcott in work connected with the manufacture, sale and application of special products such as clad steels.

Dr. Theisinger joined Lukens in August 1935, as Welding and Metallurgical Engineer and has specialized in the handling of technical matters involved in the application, fabrication and sale of the company's products.

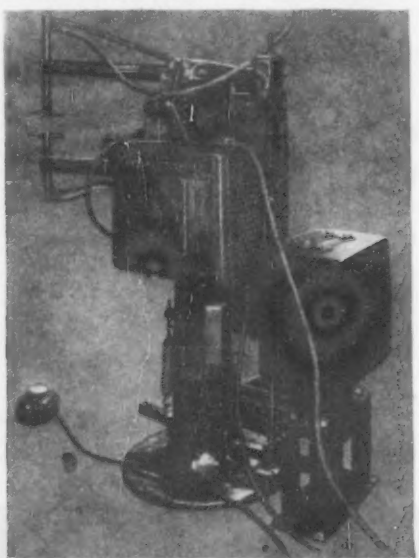
William G. Theisinger

Dr. Theisinger was born in April 1904, at Carlisle, Pa. After attending Harrisburg public schools, he became Assistant Chemist at Harrisburg Steel Corp. In 1925 he became associated with the Board of Transportation of the City of New York in the development of welding inspection.

In 1930, Dr. Theisinger matriculated at Harvard University, receiving the degree

MODERNIZE YOUR FOOT OPERATED SPOT WELDER
THE MAN WHO USES HIS HEAD GETS AHEAD

SPOT WELDERS—
STOP USING YOUR FEET



SOLENOID OPERATED 20KVA TAYLOR SPOT WELDER

By the quick, simple attachment of a Hercules Special Solenoid, which operates the arms electrically, your slow, tiresome, foot operated spot welder becomes an efficient, speedy automatic machine. The results are startling:

INCREASES PRODUCTION—30% TO 50%.

INSURES UNIFORM, PERFECT SPOT WELDS AUTOMATICALLY.

A—BY PRODUCING MUCH GREATER PRESSURE ON THE ELECTRODE ARMS.

B—BY GUARANTEEING UNIFORM PRESSURE AT ALL TIMES.

CUTS POWER COSTS.

CUTS LABOR COSTS.

ELIMINATES STRENUOUS FOOT WORK.

SKY ROCKETS THE VALUE OF YOUR SPOT WELDERS.

Units are easily attached to all makes of spot welders and are available with or without automatic timers.

SUBMIT YOUR PROBLEMS OR SEND FOR DETAILED INFORMATION.

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OTHER PRODUCTS MANUFACTURED BY HERCULES ARE:

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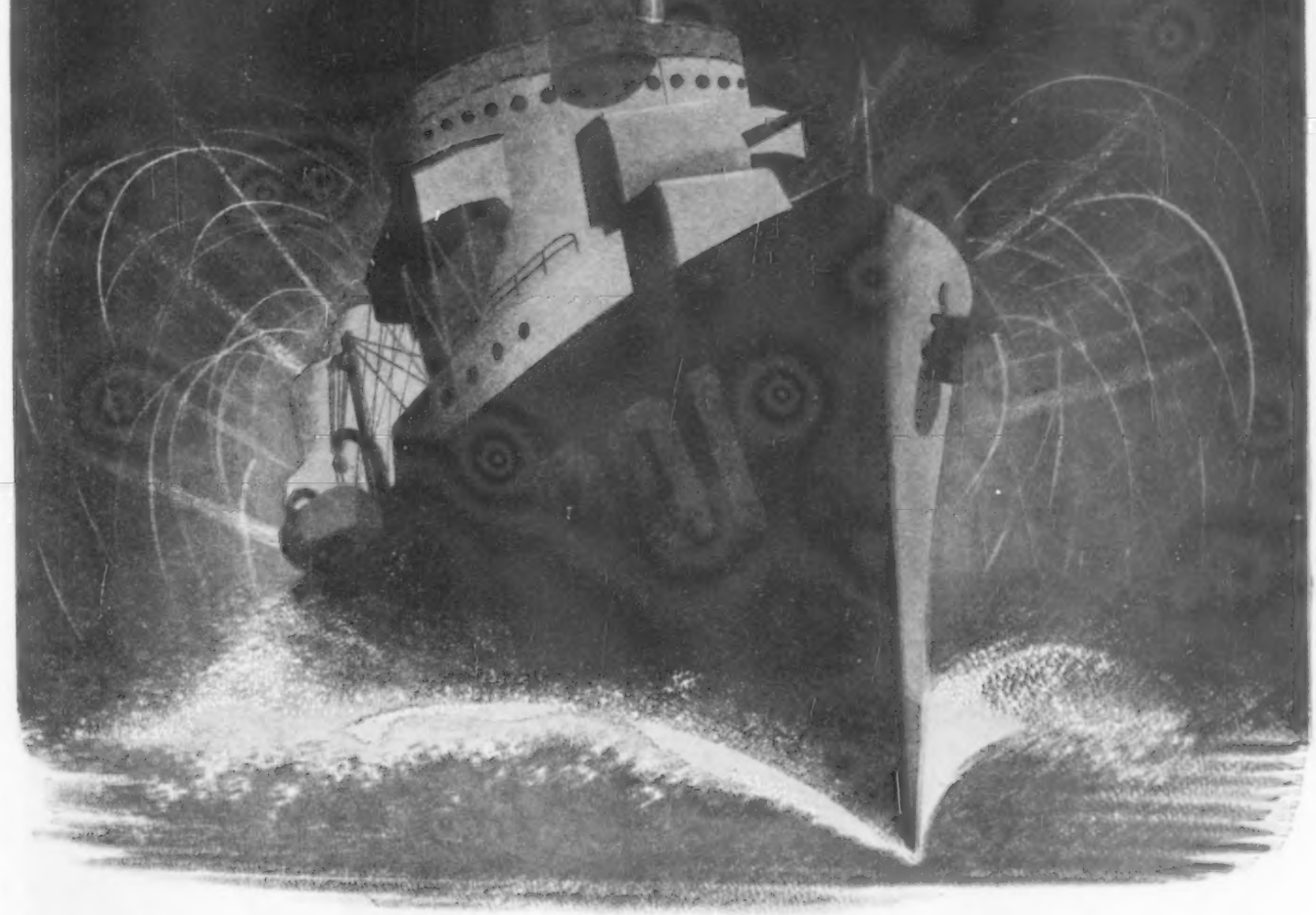
MANUFACTURERS OF THE PRECISION WELDER WITH THE STREAMLINED ARC

2416 ATLANTIC AVENUE, BROOKLYN 33, N. Y.

ON THEIR WAY THE MINUTE YOU SAY "RACO 11 ELECTRODES"



For Now We Can Guarantee You Immediate Delivery of RACO 11

That means you can have at once the electrode the Welding Foreman of one of the largest shipyards calls "the best my crew has worked with ... it's the electrode that assures X-Ray clean welds free from gas pockets and slag inclusion."

RACO 11 has proved the hard way—top-flight performance on thousands of jobs—that it is the ideal utility electrode. On AC or DC it gives superior results on mild steel in all positions. And it complies with the following specifications: A.W.S.—A.S.T.M. Filler Metal Specifications A233-42T Classification E6011; Navy Bureau of Ships Specification 46E3, Grade III, Classes 1, 2, 3; American Bureau of Shipping Specifications HIG and BIG; A.S.M.E. Boiler Code, Paragraph U68.

Immediate delivery of RACO 11 Electrodes means you can profit right away from their many advantages. Write NOW for NEW CATALOG and samples. We'll send along complete information on RACO Electrodes for every welding job.

The REID-AVERY COMPANY

DUNDALK BALTIMORE 22 MARYLAND

of Bachelor of Science in 1934. That summer he served the Western Pipe and Steel Co. as Consulting Engineer on high amperage, automatic welding. In 1935, after completion of postgraduate work at Harvard, he received the degree of Doctor of Science.

Dr. Theisinger is a member of the AMERICAN WELDING SOCIETY, the American Institute of Mining and Metallurgical Engineers, the American Branch of the Newcomen Society of England, the Franklin Institute and the Harvard Club of New York.

WHITING EMPLOYEES RECEIVE WHITE STAR

The men and women of Whiting won the Army-Navy "E" Flag on March 27, 1943, for meritorious service on the production front. Now the Under Secretary of War has again acknowledged their services by renewing the award and authorizing the addition of a white star to the original "E" flag.

FUNDAMENTALS OF ELECTRONIC CONTROL

An interesting technical pamphlet on the above subject has been issued by General Electric Co., Schenectady, N. Y. The pamphlet includes comprehensive papers on Electronic Welding Control, Seam and Pulsation Welding, Special Controls, Electronic Weld and Sequence Timers, Energy-Storage Welding, Electronic-Control Maintenance, General Electric Equipment for Resistance Welding, Index of Symbols.

SPARKS

With graphic presentation in word and in picture, the fall issue of *Sparks*, house magazine of Tube Turns, Inc., Louisville, Ky., is dedicated to telling the success story of welding in the shipbuilding industry.

Sparks, in this latest issue, carries a double-page spread showing how welding was recently employed to graft a new bow on the torpedoed destroyer *Blakely* and put her quickly back into service as good as ever. An item worthy of addition to anybody's collection of ship pictures is the full page of silhouettes of 24 of the types of ships which comprise Uncle Sam's maritime strength.

It is almost impossible for an average person to realize that there is something like a quarter of a million lineal feet of piping—about 50 miles of it—in the average ship. By chart and by picture *Sparks* shows how Tube-Turn welding fittings are enabling shipbuilders to speed up this enormous job of pipe installation and at the same time to save weight and space—in short, to do a better job of getting American ships off the ways and out on the high seas all over the world.

BASTIAN-BLESSING DIVISION MANAGER

Frank H. Fisher of Chicago has been appointed manager of the Welding & Cutting Division of The Bastian-Blessing Co., 4203 Peterson Ave., Chicago. He will supervise promotional and sales work of the company's "Rego" line and work in close cooperation with customers of "Rego" welding and cutting products.

Mr. Fisher brings to his new work a rich background of practical experience. He was previously associated with Ameri-

UNITED WELDING
YOUR LOGICAL SOURCE

On the left is a Diesel gear casing involving many sub-assemblies . . . difficult work. On the right a press . . . suggestive of many contracts successfully completed for machine tool builders.

United has the engineering talent, the facilities and the seasoned experience to fabricate all of your weldments . . . large—small—heavy—complicated or difficult . . . on long or short runs.

Submit your plans
Obtain United's quotation

THE UNITED WELDING CO., MIDDLETOWN, OHIO
Welding Fabricators of Modern Designs

Is this YOUR Cleaning Problem?
Saving Time and Conserving Manpower on These 3 Jobs:
1. Preparing aluminum for spot welding
2. Degreasing steel parts before welding
3. Preventing weld spatter from sticking
On these THREE jobs, THOROUGH cleaning is essential for best results. Oil, grease, drawing compounds, heat scale, rust or other foreign matter must be COMPLETELY removed . . . and will be if you use specially developed, safe, fast-working Oakite materials. Tell us the job on which you want further data. It's FREE . . . write TODAY!
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Technical Service Representatives Conveniently Located in All Principal Cities of the United States and Canada
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CLEANING
MATERIALS · METHODS · SERVICE

You get satisfactory welds of these dissimilar metals . . .

with

AMPCO-TRODE 10

1 Tensile strength 60,000 to 70,000 lbs. per square inch

— higher than that you get with any ordinary bronze welding rod. This equals the tensile strength of mild steel — is better than the tensile strength of most cast irons. Ampco-Trode 10 weld metal is equal in strength to manganese bronze.

2 Substantial freedom from shrinkage cracks

— because of increased "hot ductility" and higher percentage of elongation (25% to 30% elongation in 2", .505 dia.). Due to this high elongation and lack of "hot shortness," Ampco-Trode 10 readily welds most metals.

W-71

Consult your electrode supplier or write us direct.

Coated Aluminum Bronze Welding Electrodes . . .
for metallic-arc, carbon-arc, or gas welding

Ampco-Trode 10	All-purpose bronze rod.
Ampco-Trode 16 Ampco-Trode 18	For high-tensile welds requiring good ductility and subject to severe conditions of wear or corrosion.
Ampco-Trode 20 Ampco-Trode 21	For extremely hard overlay welding to meet special conditions of wear, shock, or corrosion.

AMPCO-TRODE

sent FREE

Bulletins to help you find new ways of delivering creditable results easier, faster, at lower cost — with Ampco-Trode. Detailed application data included.

TEAR OUT AND MAIL COUPON

AMPCO METAL, INC., Dept. WJ-1 Milwaukee 4, Wis.

Please send, without obligation, the following data on Ampco-Trode:

- ☐ Ampco-Trode 10 Bulletin
- ☐ General Ampco-Trode Bulletin
- ☐ Engineering Data Sheet No. 107 on repairing bronze and brass castings.

Name..... Position.....

Company.....

Address.....

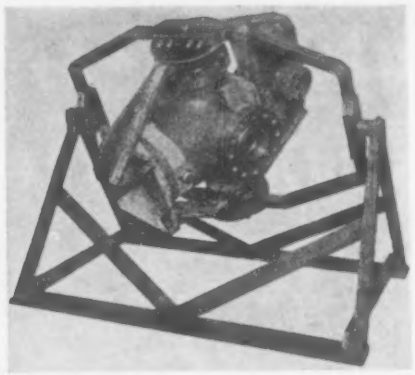
City..... (.....) State.....

can Steel Foundries of Chicago, and also served for a number of years as district sales manager of R. Cooper, Jr., Inc., General Electric Co.'s Chicago distributor. His services are available now to all users or prospective users of welding and cutting equipment to assist in their war production problems and postwar plans.

The Bastian-Blessing Co., Mr. Fisher states, is refining and improving its present products and doing research work on new models while devoting its present manufacturing facilities exclusively to the production of war material.

GIMBAL CUTS WELDING TIME 50 PER CENT

Made from salvaged bar stock by M. F. Waid, a foreman at General Electric's



Erie Works, this gimbal halves the time previously required for welding certain miscellaneous parts. Setting the work in the best welding position is easy, and the liberal distances between frames assures plenty of hand clearance for safety.

CODE FOR PRESSURE PIPING

As a result of the recommendations of the Subcommittee on Scope and Intent of the Sectional Committee on Code for Pressure Piping, B31, two new special subcommittees are being appointed to function under the procedure of Sectional Committee B31. One of these subcommittees will formulate requirements for instrument piping, the other will develop quality factors for castings and working stresses for steel castings, forgings, plate and bars, all for inclusion in the American Standard Code for Pressure Piping, ASA B31.1-1942.

It has been recognized for some time that present code requirements and standards for instrument piping are not sufficiently complete to provide adequate assurance of the safety of such piping systems. The new subcommittee to handle this assignment will consist of members of Sectional Committee B31 selected from the subcommittees that developed each section of the code representing the several types of piping, together with representatives of interested manufacturers.

The second subcommittee is being formed in accordance with a recommendation made by the recently appointed Joint Conference Committee on Piping Codes and Standards, and endorsed by the Subcommittee on Scope and Intent. This subcommittee's assignment will consist of two parts: (1) the formulation of working stresses for steel castings, forgings, plate and bars for use in designing special fittings which are not intended for application, however, to existing standard designs; (2) the development of rules for casting quality factors which will be applicable only to design of special castings.

Both of these subcommittees will be asked to develop their recommendations in the form of rules and tables similar to like data contained in the A.S.M.E. Boiler Construction Code.

COMING ANNUAL MEETING

The program Committee will meet shortly to tentatively outline the papers for the coming meeting of the Society in Cleveland next October. Suggestions are invited! Address suggestions to W. Sparagen, American Welding Society.

WANTED—WELDING CONTRACTOR

To furnish crew of about 50 welders, with or without machines, for work on Navy Craft in Ohio River Shipyard; crew to include reliable foremen and leadmen; Prime Contractor to pay wages at its prevailing shipyard rate, maintain all necessary records, secure Workmen's Compensation and Public Liability insurance, and furnish all primary articles of work such as rods, electrode-holders, etc. Please make immediate inquiry. Box 131.

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them

The Trade-Name is "ANTI-BORAX"

Ask for Them *Unequalled for Quality*

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Brax-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; No. 16 Silver Solder Paste Flux.

ANTI-BORAX COMPOUND COMPANY
Fort Wayne, Indiana

ELECTROLOY ALLOYS for RESISTANCE WELDING ELECTRODES and DIES

Spot
Seam
Butt
Flash
Projection

ELECTROLOY ALLOYS were developed specifically for the resistance welding industry. ELECTROLOY ALLOYS cover the full range of physical properties necessary to the manufacturers and users of resistance welding equipment.

Our engineers will be glad to make recommendations for your special electrodes. Submit samples or specifications.

Catalog and prices available on request.

THE ELECTROLOY COMPANY, Inc. 1600 Seaview Avenue, BRIDGEPORT, Connecticut

WROUGHT IRON SUBSTITUTION FOR COPPER

Engineers of the Bonneville Power Administration in Washington have uncovered in wrought iron a capable substitute for war-scarce copper and aluminum electrical buses.

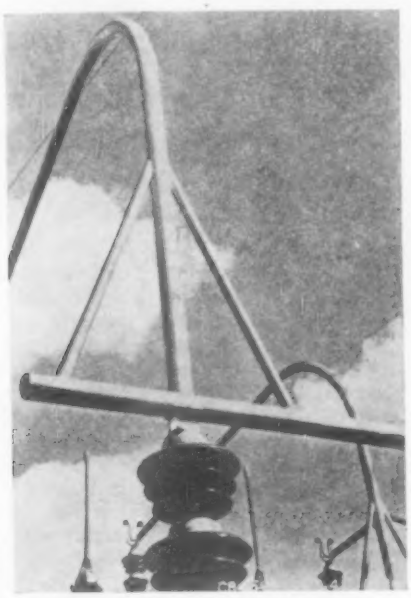


Fig. 1—The Welded Wrought Iron Pipe Bus Connection at Bonneville Consists of a Fixed Support, Y-Brace, Corona End Bell and Bend. The Pipe Is 4-In. I.P.S.

In commenting upon the suitability of wrought iron for electrical buses, as exemplified in the installations at Bonneville, Mr. Gerber, assistant Engineer, stressed its following qualifications:

1. At 115 kv. and 230 kv., the buses are found to be well within the carrying capacity of wrought iron pipe, the largest size required being 4-in. I.P.S. standard weight. The current-carrying capacity may be further increased, if necessary, by slotting the pipe along its length to break the ferrous loop, and by coating the pipe with a dull black paint to increase the heat emissibility.

2. Wrougl.t iron has a high modulus of elasticity, permitting long spans, particularly with ice and wind loading, thus saving on insulators, fittings and supports.

3. It has good corrosion-resisting properties. Paint gives it additional protection and is easy to apply.

4. Welding is an easy, quick and economical way of joining the pipe into whatever bus arrangement is desired. All clamp-type fittings are eliminated, since welding produces joints that have high electrical efficiency as well as permanence.

5. It expands less than copper or aluminum, necessitating fewer expansion joints.

6. It costs less than aluminum or copper pipe of same size.

7. Welded buses reduce corona formation.

Fig. 2—First Recorded Installation of Wrought Iron Electrical Buses Is Announced by Engineers of the Bonneville Power Administration. With Copper and Aluminum Unavailable, 8000-Yr.-Old Wrought Iron Has Been Found to Be a Capable Substitute. The Joints Are Welded

The wrought iron buses at Bonneville were finished by first removing the protective asphalt varnish from the pipe and by cleaning it with an abrasive, then by applying a coat of synthetic red lead and two coats of aluminum paint.

YEAR-END INCENTIVE PAYMENTS BY THE LINCOLN ELECTRIC CO.

Saying that he refuses "to renegotiate his own workers," despite renegotiation proceedings now pending between his company and the Navy Department, J. F. Lincoln, President of The Lincoln Electric Co., on December 11th announced the distribution of the year-end pay averaging over $2250 per employee. The payments were computed on the same basis as that of the previous ten years in which the earnings of a man, combined with his years of service and his development, gaged the amount of money he received.

These year-end checks which were distributed at the plant at noon, ranged from $25 in the case of a newcomer, to $50,000 in the case of an engineer, whose genius produced a new type of welder which cut the cost of production by nearly 50%.

Ninety per cent of the distribution, which totalled approximately $3,000,000 went to so-called factory employees and office workers. The only people who did not participate in the distribution were J. C. Lincoln, Chairman of the Board, and J. F. Lincoln.

"By producing" Lincoln said, "at the rate of more than four times that of any other company manufacturing a similar type of product, our workers are entitled to rewards somewhat proportionate to their participation in this remarkable production achievement."

Because of this plan over the last ten years, enormous reductions in cost and selling price have been achieved, company records show. A standard welding machine which originally sold for $1500 now sells for $180. A pound of welding electrodes originally selling at 15¢ now sells for 4.8¢. These prices are said to be less than half the price of motor-generator sets of the same capacity used for other purposes.

"One would expect," Lincoln said, "that during a period of war, when the country is fighting for its life, an achievement of this kind would be encouraged. Exactly the opposite is being done.

"Because of the incentive system which has reduced the labor cost per piece by more than 50%, but which has increased the yearly income of the worker, the Treasury Department has seen fit for the year 1941 to assess the company $1,600,000 because they state we paid our men too much, in spite of the fact that the pay per piece was less than any manufacturer making a comparable product. Because we manufactured so efficiently and sold at such a low price, we have been renegotiated to the tune of $3,250,000, while no other manufacturer making the same product has been renegotiated on that product.

"Because of the efficiency of the operation and the reducing of the prices as rapidly as the cost has been reduced, the welding industry has saved the Government over the last two years more than $100,000,000 compared to comparable products. If the same incentive and consequent efficiency were obtained generally in the war effort, there would be a reduction of at least 50% in the cost of this war and a doubling in its tempo."

SAFETY BOOK

The National Fire Protection Association of 60 Batterymarch St., Boston 10, Mass., has issued a book of 502 pages on *The National Fire Codes for Flammable Liquids, Gases, Chemicals and Explosives* compiled by Robert S. Moulton, Technical Secretary N. F. P. A. One section relates to Gas Systems for Welding and Cutting—Standards for the Installation and Operation of Gas Systems for Welding and Cutting.

YEAR BOOK

As previously announced the Year Book this year will be published in February 1944 instead of December 1943. It will no longer be issued as a part of THE WELDING JOURNAL. Owing to government restrictions on paper, a limited edition will be published. Copies will not be sent out as heretofore to the entire membership list. Members desiring a copy, however, may obtain one by writing to the Secretary requesting a copy.

NEW PRODUCTS

The Society assumes no responsibility
for the validity of claims in this Section

WELDING-MASK COVER GLASS

Bullock "Dalite" Processed Cover Glasses are regular glass processed with a protective coating, either blue-tinted or clear, that is intended to shield glass against heat breakage and damage from metal splatter. "Dalite" is completely covered with this tough, baked-on protective coating designed to prevent pitting, peeling and easy marring by scratching.

Blue-tinted glass is offered for added protection to workers' eyes—checking harmful rays and glare. "Dalite" is processed to offer substantial reductions in time otherwise wasted in replacing broken or easily pitted cover glasses. Hopkins Engineering Co., 2-159 General Motors Bldg., Detroit 2, Mich., or 230 North Michigan Ave., Chicago 1, Ill. L. H. Bullock Co., Mfr., Berkeley, Calif.

ALL-POSITION ELECTRODES

"Raco" Type H-D No. 11 A.C. Electrodes are designed to produce All-Position welds of highest quality. These electrodes are particularly adapted to X-ray perfect welds such as required in shipbuilding, pipe-line construction, boiler work, etc. The arc characteristics are excellent; the slag is easily controlled; and the weld metal is smooth and sound. The weld metal quality is superior to that produced by the "old line" reverse polarity electrodes. No special training is required if operators are familiar with d.-c. all-position welding.

"Raco" H-D No. 11 Electrodes may be used on direct current with excellent results. For further information write The Reid-Avery Co., Dundalk, Baltimore, Md.

SHIPBOARD INSTALLATION OF FIBERGLAS BOARD

An interesting exhibit at the 25th annual meeting of the National Metal Congress in Chicago, October 18th to 22nd, was the exhibit of the Nelson Specialty Welding Equipment Co., demonstrating the use of the Nelson automatic electric arc stud welder in installing Fiberglas insulation board on ships.

Engineers, physicists and business men crowded about the Nelson booth to watch trim girl welders fasten the Fiberglas board to steel plate, using the welding gun invented by 36-year-old Ted Nelson who a few years ago was a welder in the Mare Island Navy Yard.

Shipyards are now using the Nelson stud welder to secure wood decking, insulation,

electric fixtures, switch boxes, multiple cable runs, and for other shipboard installations where whatever is being installed must be secured to steel plate. A fast operator can weld 1000 studs in an 8-hour shift, saving 75% of the time required for hand welding.

The Nelson gun holds a steel stud approximately 1/8 in. from the steel plate during the time an electric arc burns between the stud and the plate. The timer then shuts off the electricity and the gun plunges the stud into the plate, causing the molten end of the stud and the molten puddle of steel on the plate to fuse completely, resulting in a dense, solid end-weld.

LOW-COST WELDING POSITIONER

In the line of welding positioners recently introduced by Harnischfeger Corp., Milwaukee, is this 2500-lb. capacity model WP-2 which, according to the manufacturer, is priced in the lowest brackets for its class. Featuring flexibility of use, simplicity and easy operation, it is designed for production line welding as well as job work, maintenance, etc. As in senior models, construction throughout is all-welded rolled steel. Table is 42 in. diameter, has 18 handy radial slots for mounting fixtures and is turned manually to suit welding speed. Tilting is controlled by hydraulic power with 135° beyond horizontal position attainable. Both table movements have positive locking devices. Telescopic column with self-locating stops provides for table elevation from 28 in. minimum to 60 in. maximum from floor, depending on type of mounting. Portable or column-in-floor mountings are available. The design is marked by sturdy and safe construction in all parts. For example, the removable table is held to platen

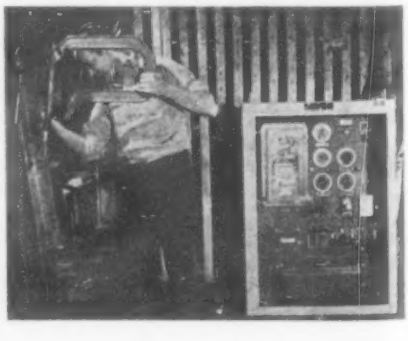
by ten heavy bolts. Platen index is welded integrally with king pin which is held in position by large safety lock nut. No gearing is exposed. Available extra equipment includes electric power or ring gear and handwheel assembly for table turning with foot or push-button control, higher than standard columns in increments of one foot and roller equipped outboard supports for handling long or large weldments. Equipment for power table rotation, constant speed of 1 rpm may also be had, and all table assemblies are readily interchangeable in the field. Complete specifications and literature available from manufacturer on request.

WELD RECORDER

General Electric weld recorders are materially helping to produce high-quality welds, at the same time effecting a saving of time and labor. Shown mounted with a synchronous thyratron spot-welding control in a portable case is one of these recorders in operation at the E. G. Budd Manufacturing Co., Philadelphia, Pa., where a large number of them are being used to fabricate stainless steel parts for aircraft.

The weld recorder registers on a paper chart excessive variations in the current to the welding machine, which might cause weak spot welds, sounds a bell to warn the operator and automatically shuts down the machine.

The recorder is used in conjunction with a synchronous thyratron spot-welding control equipped with a removable sequence panel and a voltage regulator. The latter, when used with the heat con-



Welded Monel Chain Better by 7 to 1 Margin

Youngstown Welding and Engineering Co. helps steel mill cut pickling cost per ton of finished steel... output substantially increased

Here's a record of trouble-prevention and economy that's highly important to users of pickling equipment.

It's the success story of welded Monel chains designed and fabricated by the Youngstown Welding and Engineering Co., and used in mechanical picklers by one of the country's largest producers of alloy steels.

Before the war the mill used the Monel chains to pickle alloy steels in 10% sulfuric acid at 150° F.-165° F. Now with the mill at wartime speed, Monel chains do their part . . . reducing down time . . . keeping production rolling!

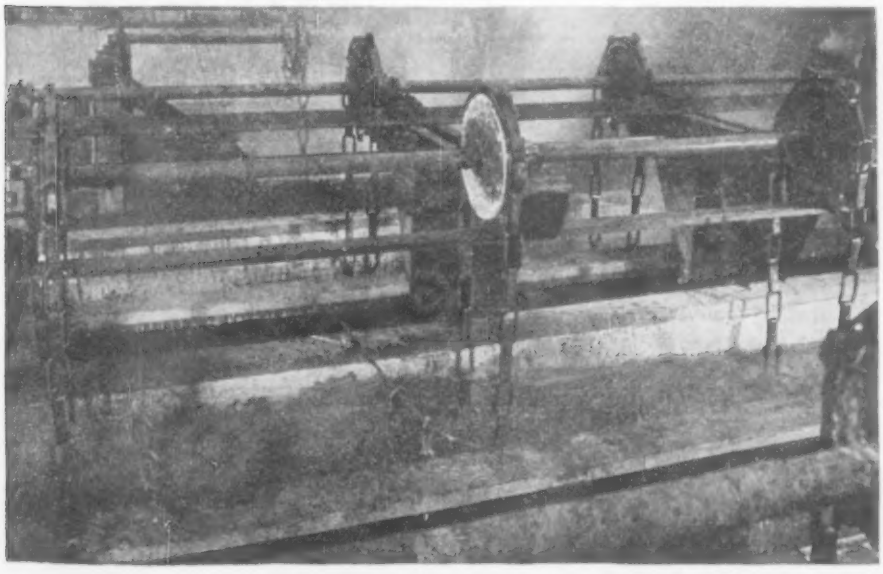
When cast alloy chains were used, the life was short and even during the short life, frequent repairs were necessary.

But with Monel chains the mill gets seven times the life without any maintenance. Handling 5 ton loads, welded Monel chains, average total loads of 20,000 tons during their service life.

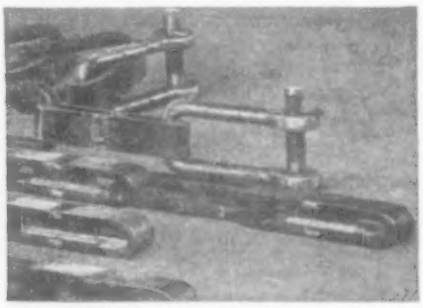
A serious problem with the original chains was copper-flash, which reduced the response of the alloy steels to the carburizing treatment. Monel chains eliminated this hazard completely.

Welded Monel sling chains are also used in loading the picklers.

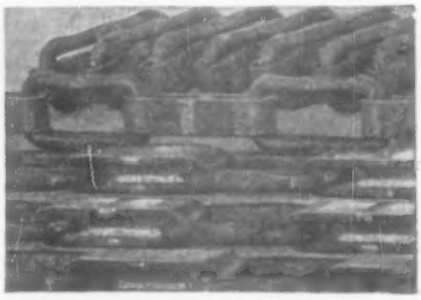
Tough, strong and highly resistant to corrosion, welded Monel is uniquely suited for pickling use. Further information about the use of Monel in pickling will be sent to you on request.



Mechanical picklers at work in one of America's large steel mills. Average load on pickler is 5 tons; tubes and bars up to 6" O. D. and 20 feet long are pickled. Chains move 20 feet per minute.



Close-up of the one mechanical leg joint on this endless welded pickling chain.



Further detail of welded Monel links. Chain of this type has handled up to 20,000 tons of steel in pickling operation, is still in service.

MONEL

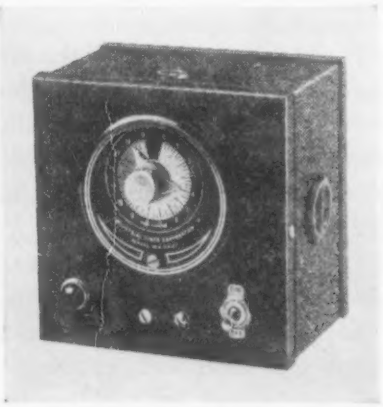
"Monel" is a registered trade-mark of The International Nickel Company, Inc., which is applied to a nickel alloy containing approximately two-thirds nickel and one-third copper.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL STREET, NEW YORK 5, N. Y.

trol by the phase-shift method, automatically compensates for variations in line voltage, thus tending to hold the welding current constant. A half-cycle protective relay in the control also warns the operator should one of the thyratron tubes fail to function properly.

SIGNALLING TIMER

The new, Series S, Signalling Timer is designed to command visual and audible attention the instant a time interval is completed. It is exceptionally versatile in applications in that it provides for the automatic closing or opening of a circuit



at the end of elapsed time, and operates additional buzzers, bells or lights at remote locations. These timers are also used in welding operations. For further information address Industrial Timer Corporation, 117 Edison Place, Newark, N. J.

JESSOP CATALOG

The Jessop Steel Company of Washington, Pa., pioneers of stainless-clad and other composite steels, announces the publication of a new catalog on Jessop Stainless-Clad Steel.

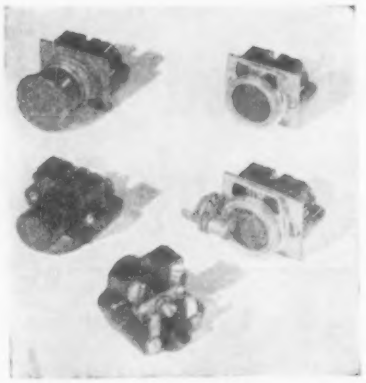
Included in this helpful literature is information on analyses, applications, manufacture, fabrication, styles of heads and standard size of sheets and plates. It also gives a comprehensive explanation of the exclusive patented "assembly method" used in producing Jessop Stainless-Clad.

Of special interest to fabricators contemplating the use of this composite metal are the sections on deep drawiug, grinding, polishing, cleaning, gas-cutting, riveting, soldering, welding, etc.

Copies of the Jessop Stainless-Clad Steel booklet are available without obligation on request.

PUSH-BUTTON UNITS

A new line of standard-duty push-button units designed for flush or surface mounting on machine tools, welding controls and similar equipment, has been announced by



the Industrial Control Division of the General Electric Co.

Available in both the pendent and the oilproof types, these units are made of smooth, hot-molded, moisture-resisting phenolic compound. The buttons are large in diameter and slightly concave to fit the tip of the finger. The responsive, double-break contacts are of fine silver and have a steel back projection, protected by rust-resisting plating, welded to the contact supports. The small size of these units permits mounting several of them in a relatively limited space.

Castolin Eutectic®

EUTECTIC*

(Means Lowest Binding Alloy)

LOW TEMPERATURE WELDING

NO GENERAL PREHEATING REQUIRED FOR WELDING CAST IRON

PROBLEM

How to repair this cast iron exhaust with a color matching, heat resistant weld? With high temperature, fusion welding there was great risk of stresses, new cracks, and distortion even in the hands of the most skillful welder. Bronze brazing could not be used since the job requires a perfect color match.

SOLUTION

Eutectic Low Temperature Welding Alloy No. 14 was tried. Its low binding temperature (950-1400°F) eliminated risk of stresses, new cracks, and distortion. Many jobs require only slight local preheat • Weld has high heat resistance • Easily machinable • Perfectly color matching.

EUTECTIC LOW TEMPERATURE WELDING ALLOY RODS FOR CAST IRON

Alloy No.	Purpose	Binds at °F.	Tensile Strength, Lbs. p.s.i.	Machinable
15	Filling cracks, defects	354° - 600°	1,140 (pressure)	Yes
14	High strength joining	950° - 1400°	48,000	Yes
16	Joining cast iron to steel	1300° - 1600°	117,000	Yes
24B	Cast iron not subject to stresses		38,500	Yes
24	Cast iron subject to stresses		20-30,000	Yes

For oxy-acetylene: Eutectic Nos. 14, 15, 16. For AC-DC Metallic Arc: Eutectic Nos. 24, 24B.

Chart of 43 Eutectic Alloys for every metal and every welding job available free upon request.

36 PAGE "KNOW-HOW" MANUAL E —WRITE TODAY!

Tells How Eutectic Can Help You!

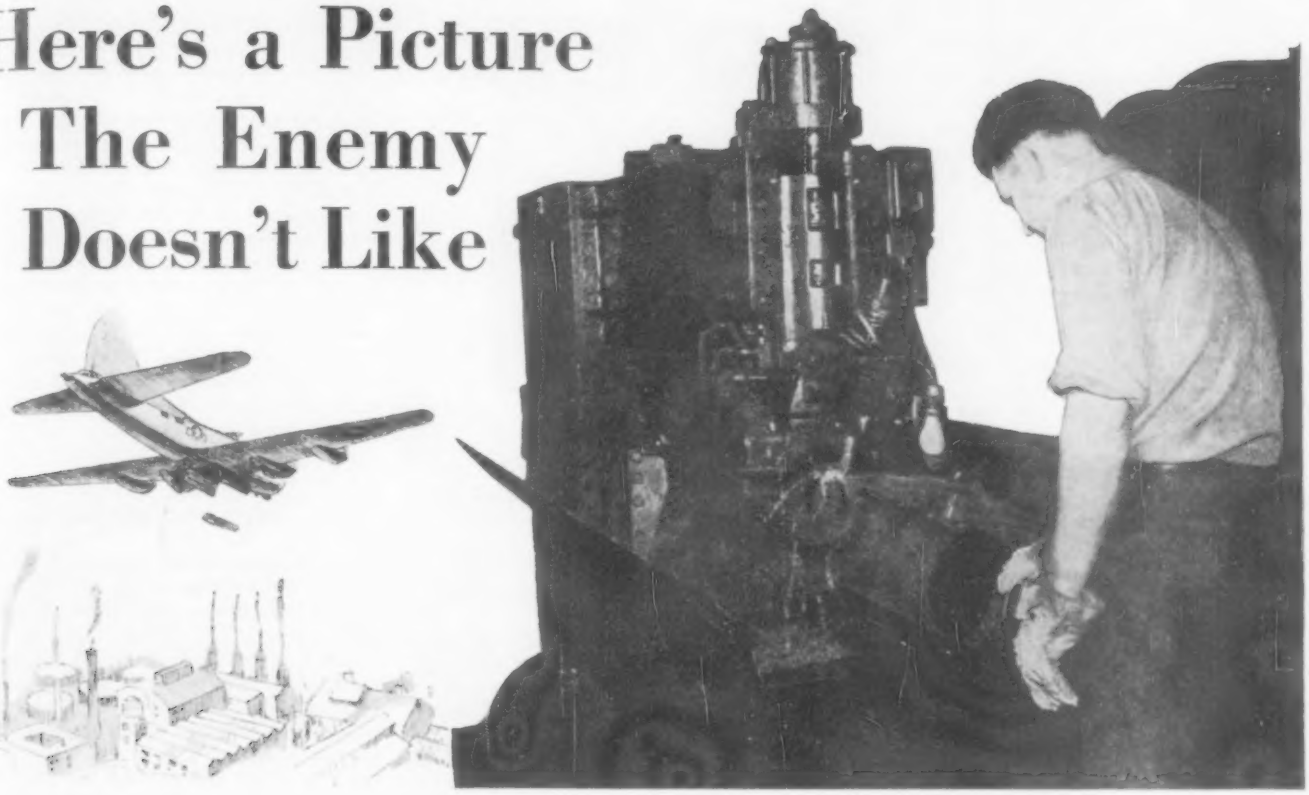
*Reg. U. S. Pat. Off.

EUTECTIC WELDING ALLOYS COMPANY

Originators of the Low Temperature Welding Process

40 WORTH STREET, NEW YORK, 13, N.Y.

Here's a Picture The Enemy Doesn't Like



WHEN a large mid-western war plant converted to the manufacture of an important chemical bomb, it looked for a while as if production would be seriously limited. Chief cause of this threatened bottleneck lay in the joining of the cylindrical center section—the operation you see pictured here.

Today, thanks to Mallory skill and experience, the problem is solved and the bottleneck removed. The core of the bomb is quickly joined by Mallory resistance seam welding electrodes. These are made of tough Mallory 3 Metal. Throughout the entire welding operation, wheel and weld are constantly cooled by a running stream of water.

As a result of this combination, three highly desirable objectives have been obtained. Welds are strong and of excellent quality. Excess warping is avoided, and dimensional stability assured. Finally, the welding wheels go through long production runs before it is necessary to dress the welding face.

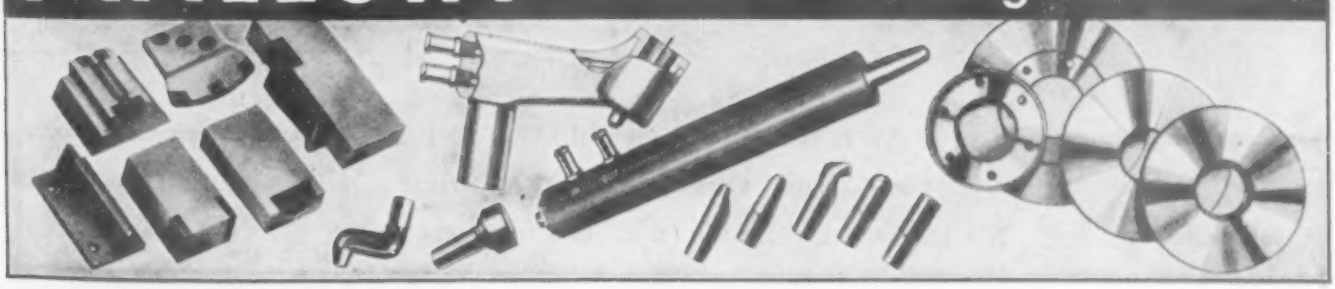
Naturally, this is a story the enemy doesn't like. But then, the whole trend of Mallory advancement is running against the Axis tide. In scores of other factories today, Mallory engineering has resulted in longer electrode life . . . welds of higher strength and consistency . . . faster, better wartime production—frequently at lower cost. This same experience is ready to be of service to you—no matter what your welding problem, or to what kind of product it happens to apply. Write today for the comprehensive Mallory Resistance Welding Data Book.

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

Your Pledge of Faith—Government War Bonds

P. R. MALLORY & CO. Inc

MALLORY *Standardized Resistance Welding Electrodes*



TUNGSTEN ELECTRODES

Callite Tungsten Corporation of Union City, N. J., pioneers in tugsten metallurgy for over 25 years, have applied their accumulated knowledge and experience to the development and production of better, time-saving tungsten electrodes for atomic hydrogen, helium and argon arc welding. These welding methods are widely used in war industries where they have been found quick and efficient for the manual and automatic welding of such metals as aluminum, duraluminum, nickel, chrome, monel metal, molybdenum steels, copper, stainless steel, brass and bronze.

Callite Bulletin No. 154, just issued, describes the application of Callite tungsten electrodes by atomic-hydrogen, helium and argon arc welding and gives complete data on the Callite tungsten electrodes available—their physical properties, dimensions and current range in amperes. Users of welding electrodes will find this bulletin extremely interesting and informative. Copies may be had on request to Callite Tungsten Corp., 540 Thirty-ninth St., Union City, N. J.

SPOTLIGHT FOR ARC-WELDING OPERATORS

A new spotlight designed to provide glareless illumination of sufficient intensity for an arc-welding operator to see his work distinctly through the dark lens of a welding helmet prior to striking the arc, has been announced by the Electric Welding Division of the General Electric Co. The new spotlight (Cat. 89X391) is especially desirable for production-line welding in which the establishment of the arc must be made quickly and accurately, such as in the welding of thin materials, light alloy castings and aircraft parts.

The spotlight is designed to increase production by saving time and reducing operator fatigue, since it is not necessary for the operator to lift his helmet before striking the arc. It also reduces spoilage of exacting work because the operator can strike the arc precisely where required.

Mounted on an upright, telescoping metal standard and set firmly in an $18^1/_2$-in. diameter, 30-lb. cast-iron base for stability, the spotlight consists of three 300-watt reflector spot lamps surrounded by a circular shade. Rated to give 1000 hr. of continuous operation at 120 v., the lamps are mounted in adjustable porcelain holders, so that the area covered by the light beam can be increased from a single, sharp spot 7 in. in diameter to a clover leaf shaped pattern approximately 17 in. across at its widest point.

Controlled by a foot-operated switch which is depressed by the operator while the arc is struck, the unit is equipped with a 10-ft., oilproof, heavily jacketed cable, with plug for connecting the light to the electric circuit. Except for the inside telescoping section of the standard, the entire unit has an attractive black crackle finish, and is furnished completely wired and ready for operation.

WELD BEND TESTING

The Tempilscale for weld bend testing is providing to be an invaluable aid wherever welding has to meet required standards.

The pad contains 25 sheets (approximately 3 x 6 in.). Each sheet has one edge carefully ruled in $^1/_{50}$ths of an inch, making it possible to measure up to 3 in. to the nearest $^1/_{100}$th of an inch. The black-on-white graduations are easy to read and help to achieve good accuracy.

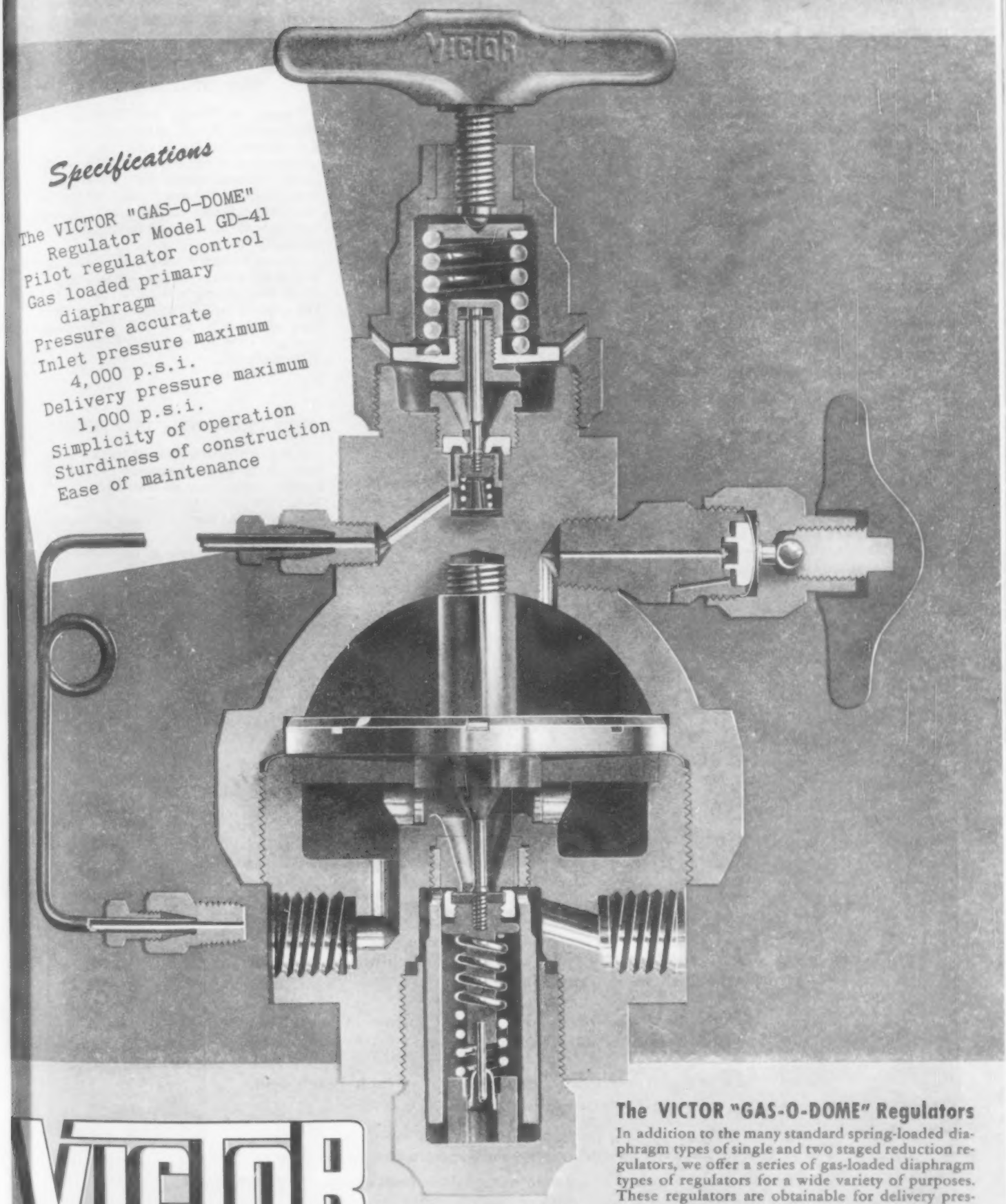
Printed on rag-content paper, the scale not only offers a practical substitute for the hard-to-get and easy-to-lose flexible steel rule, but is actually easier to use

National
Carbide
IN THE RED DRUM

EFFICIENT
ECONOMICAL
DEPENDABLE

FOR WELDING and CUTTING
Use National Carbide in the Red Drum
60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York, N. Y.

REGULATOR BY VICTOR



Specifications

The VICTOR "GAS-O-DOME"
Regulator Model GD-41
Pilot regulator control
Gas loaded primary
diaphragm
Pressure accurate
Inlet pressure maximum
4,000 p.s.i.
Delivery pressure maximum
1,000 p.s.i.
Simplicity of operation
Sturdiness of construction
Ease of maintenance

VICTOR

ARMY E NAVY

DISTRIBUTORS
FROM
COAST TO COAST

The VICTOR "GAS-O-DOME" Regulators

In addition to the many standard spring-loaded diaphragm types of single and two staged reduction regulators, we offer a series of gas-loaded diaphragm types of regulators for a wide variety of purposes. These regulators are obtainable for delivery pressure ranges up to 5,000 p.s.i.—pilot regulator or valve loading controls. If you have unusual pressure regulating problems, write today for the Victor "Gas-O-Dome" Regulator Bulletin.

VICTOR EQUIPMENT COMPANY
844 FOLSOM STREET • SAN FRANCISCO

because it can be more readily applied to sharply curved surfaces. The face of each sheet provides for a permanent record of the test data, while the back carries a handy table of figures, giving the required elongation to cover practically every conceivable case.

One of the chief merits of the Tempilscale lies in its prevention of borderline failures in weld bend testing. Under customary methods the bending is interrupted a few times to measure the elongation with a flexible steel rule. Very frequently the required elongation is overrun sufficiently to cause a borderline failure of the weld.

LENSES

Noviweld-Didymium lenses for flame welders are now available in a No. 3 shade, American Optical Co. of Southbridge, Mass., announces. With the addition of this lighter shade, which is particularly useful for welders working on aluminum, Noviweld-Didymium is now available in four shades: 3, 4, 5 and 6.

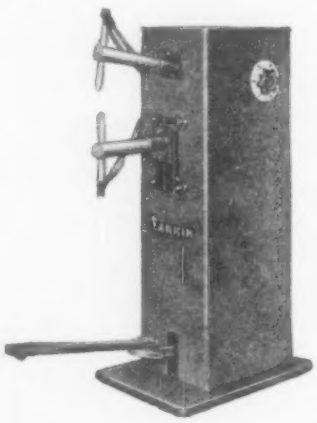
The concern states that lenses made from this glass absorb sodium flare, thus enabling flame welders to see working areas more clearly. In addition, the glass protects eyes against both ultraviolet and infrared radiation. Ground and polished to ophthalmic standards, the lenses preserve orange and red color values so that welders can see the red hot bead and the molten metal in brilliant colors.

The lenses, adds the concern, can improve the efficiency of welders and the smoothness of their welds. As a result, chipping, grinding, wire brushing and other secondary operations are reduced in time and cost.

SPOT WELDER

Larkin Lectro Products Co. manufactures a complete line of resistance welders, spot, seam, butt, projection, as well as resistance heating units. These machines vary from 1 to 75 kva. and include water-cooled tips, adjustable pressure pivot-type foot pedal, six or more heat stages and automatic trip switch.

They are equipped with precision timers and contactors, high power factor correction, air or motor drives at additional cost.



The company has also inaugurated a complete engineering service for resistance or arc welder problems.

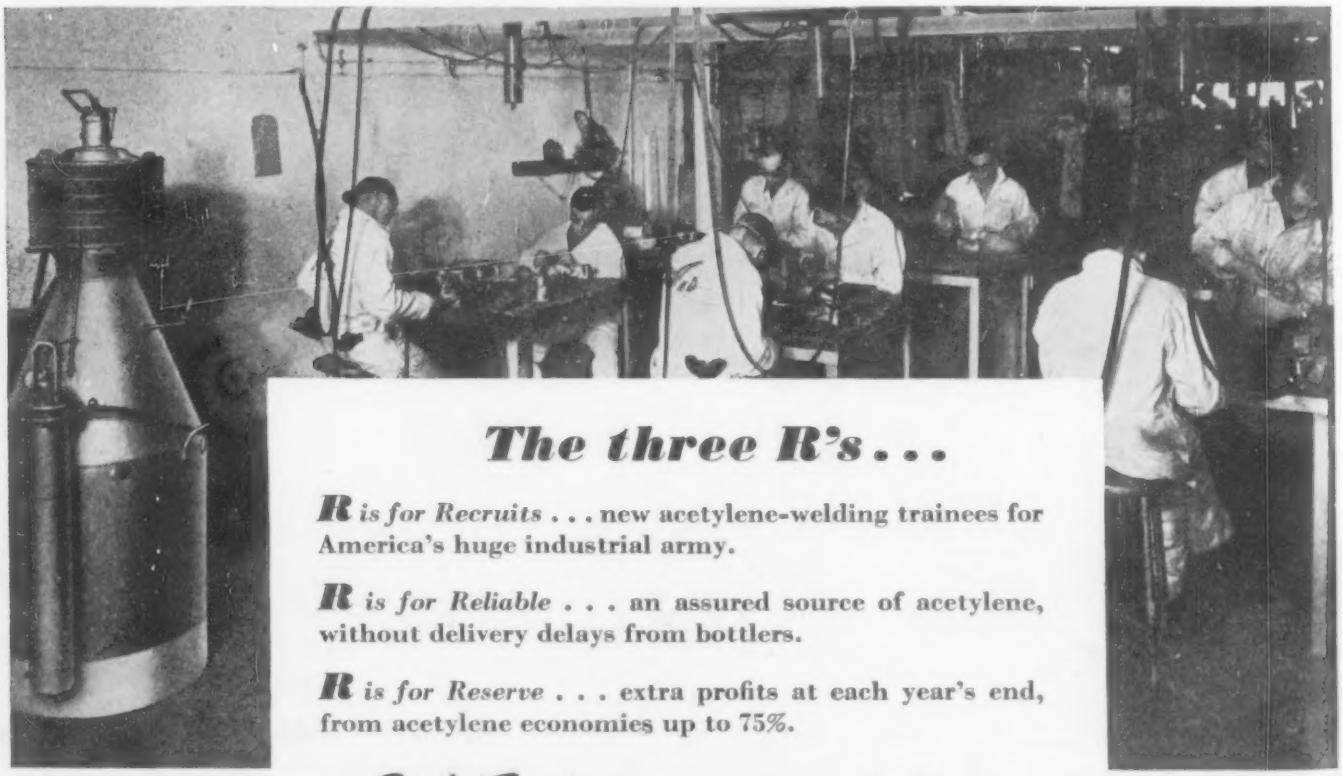
SUSTAINING COMPANY

Tippett & Wood, 162 Howard St., Phillipsburg, N. J., organized in 1865, are pioneers in the design, construction and erection of elevated tanks and standpipes, railroad turntables. Build small steel highway bridges. Build buoys for the United States Government. Export materials to Mexico and South America. Specialize in power house construction, penstacks, boilers, smokestacks, coal bunkers, boiler casings and air ducts. Tanks of all sizes, shapes and materials. Build kilns, driers, ball mills, bins, dust collectors, elevator buckets and other plate products used by cement, chemical and industrial plans.

INSTRUCTIONS FOR SILVER BRAZING

A new instruction sheet for torch brazing with silver alloys has been issued by Handy & Harman, 82 Fulton St., New York 7, N. Y. It is available in bulletin form and in the form of a chart for mounting on the wall.

Copies are available in either form to anyone who writes for one.



The three R's . . .

***R** is for Recruits* . . . new acetylene-welding trainees for America's huge industrial army.

***R** is for Reliable* . . . an assured source of acetylene, without delivery delays from bottlers.

***R** is for Reserve* . . . extra profits at each year's end, from acetylene economies up to 75%.

Sight-Feed Acetylene Generators point the way to the three R's . . . why not apply their demonstrated advantages to YOUR business?

THE SIGHT FEED GENERATOR CO. • SALES: RICHMOND, IND. • FACTORY: W. ALEXANDRIA, OHIO

Here, Adolph, are samples
of yesteryear FACTS now turned FLOPS

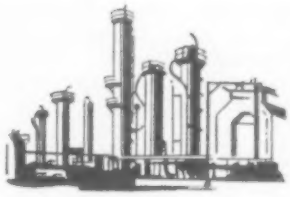
FLOPPED FACT 1:
"You can't produce all-welded ships" . . . . . .

....Recourse to arc welding has filled the seven seas with them.

FLOPPED FACT 2:
"You can't arc weld high-temperature, high-pressure piping" . . . . . .

....The one safe way is through recourse to arc welding.

FLOPPED FACT 3:
"You can't weld cracking stills" . . . . . .



....Without recourse to arc welding—our armed forces would be without high octane gas.

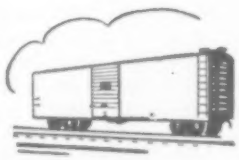
FLOPPED FACT 4:
"You can't produce army tanks with arc welding" . . . . . .

....Through recourse to arc welding—it's the only kind they're producing today.

FLOPPED FACT 5:
"You can't erect buildings by arc welding" . . . . . .

....Savings in steel and money are represented in thousands of structures of every type—through recourse to arc welding.

FLOPPED FACT 6:
"Railroad cars are taboo for arc welding" . . . . . .



....Watch them rolling the rails in every state—through recourse to arc welding.

THE LINCOLN ELECTRIC COMPANY • CLEVELAND 1, OHIO

America's greatest natural **recourse**

ARC WELDING

SECTION ACTIVITIES

BIRMINGHAM

"Naval Construction" was the subject of the November 22nd meeting of the Birmingham Section held at the Alabama Power Co. Building. R. W. Brendle, Welding Engineer, Tampa Shipbuilding Co., presented an unusually interesting paper, which created more interest than has been experienced for quite some time. There were approximately 60 present at the meeting. Mr. Brendle's paper was rather unique in that instead of following the usual practice of talking about good welding designing he also talked about faulty designing.

A restricted Navy motion picture "Full Speed Ahead" was both entertaining and instructive.

Unfortunately, Boyce Williamson, Naval Architect and Marine Engineer, was taken ill just before this meeting was held, but R. E. Jones, Chief Engineer, Ingalls Iron Works Co., substituted for him and did a splendid job in conducting the Question and Answer period. Credit was given Mr. Jones for his ability to create more interest in this Question and Answer period by the membership than has been shown in some time.

CHATTANOOGA

The Chattanooga Section of the AMERICAN WELDING SOCIETY had "something to be thankful for" Tuesday, November 23rd, when a real turkey dinner with all the trimmings was served at the Hotel Patten for members and visitors. Over 60 persons turned out for the "eats" and the entertainment.

The principal speaker for the occasion was R. W. Brendle, Welding Engineer of the Tampa Shipbuilding Co. of Tampa, Fla. His subject was "Welding in Naval Construction" and his talk was illustrated by slides. He held his audience through both an inspired talk and also a spirited Question and Answer session.

The after-dinner speaker was C. M. S., McIlwaine of McCallie School, Chattanooga, who talked on his "Seventeen Years in Japan."

A. U. S. Navy motion picture entitled "Full Speed Ahead" was presented.

CHICAGO

The Chicago Section of the AMERICAN WELDING SOCIETY held its regular monthly meeting on Friday, November 12th, in the Peoples Gas Light and Coke Co. Auditorium. A movie, "This Amazing America," was shown through the courtesy of the Pennsylvania and Central Greyhound Lines. Then followed the feature address by E. J. Wellauer, Supervisor, Research and Metallurgy, The Falk Corp., Milwaukee.

Mr. Wellauer discussed some practical aspects of welding metallurgy, with particular emphasis upon the properties of various metals and problems pertaining to the welding of cast steel. Slides of unusual applications of welding were also shown. The Falk Corp. is one of the world's largest producers of large gear reduction units and power transmission equipment; as such, it has one of the largest heavy section weld shops in the Milwaukee area.

CINCINNATI

At the December meeting held on the 7th at the Hotel Alms, the subject, "The Unionmelt Welding Process," was presented through movies, slides and speaker by The Linde Air Products Co.

CLEVELAND

The regular meeting of the Cleveland Section of the AMERICAN WELDING SOCIETY held Wednesday, December 8th, at 8 o'clock at the Cleveland Engineering Society, was a grand success.

The speaker of the evening was E. J. Wellauer, Supervisor of Research and Metallurgy, The Falk Corp., Milwaukee, Wis., on the subject, "Castings, Their Uses in Weldments." His talk approached the factors of metallurgical problems associated with welded castings and was followed by a discussion of engineering properties of welded castings, and finally, practical examples of the use of steel castings in weldments.

Mr. Wellauer's broad knowledge and experience in metallurgical research makes him particularly well qualified to discuss subjects dealing with the characteristics and properties of metals and their adaptability to modern welding processes.

Mr. Wellauer has been responsible for many outstanding developments in the manufacture of his company's products which include gear unit transmissions for industrial, marine and rolling mill drives, speed reducers, steel castings and miscellaneous items produced by welding and machining operations.

A graduate of Marquette University, Mr. Wellauer completed the University's electrical and mechanical engineering courses and later received his master's degree in metallurgical engineering at the University of Wisconsin.

George H. Scragg, Director of Advertising and Sales Promotion, White Motor Co., gave a movie talk entitled, "Aviation Memoirs."

Dr. Kent Van Horn, Aluminum Co. of America is scheduled for the January 12th meeting. His subject will be, "Radiographic Inspection of Welded Plates and Castings."

COLUMBUS

R. N. Baughman, Manager, Cleveland Office, Magnaflux Corp., discussed the subject "Magnaflux and Zyglo Inspections" at the December 10th meeting held at the Southern Hotel. A dinner preceded the technical meeting.

DETROIT AND FLINT

Two outstanding authorities, W. J. Conley, Lincoln Electric Co., and F. A. Lee, International Harvester Co., were the speakers at the December 2nd meeting of the Flint Division and the December 3rd meeting of the Detroit Section. Professor Conley was formerly chairman of the Department of Engineering at the University of Rochester. Professor Conley presented the story of the Metallurgy of Welds and how welding affects the parent metal in language that all could understand. "Spot Welding of Heavy Alloy Plate for Postwar Work" was Mr. Lee's subject. Spot welding in ordnance materials was considered noncommercial up to the time that the International Harvester Co. undertook to prove the project feasible from the commercial point of view. They substantiated their process by installing huge new batteries of specially designed resistance welders for the very job discussed by Mr. Lee. This paper created tremendous interest and was well received.

INDIANA

The Indiana Section of the AMERICAN WELDING SOCIETY held their November dinner meeting at the Central Y.M.C.A. at Anderson, Ind., on the 19th.

There has been exceedingly fine cooperation and interest shown by the membership this season; all dinners thus far have been sellouts, the Anderson dinner totaling 105 present.

Indiana was fortunate in getting an authority on low-temperature welding as its guest speaker. H. W. Foege is manager-engineer of the Midwest territory for The Eutectic Welding Alloys Co. of New York.

Mr. Foege presented a very interesting program which included a discussion of this new type of welding application, and used movies, as well as slides, to illustrate more fully.

The program officers of the Indiana Section are to be congratulated for doing such a fine job in obtaining such outstanding authorities on welding as guest speakers.

LEHIGH VALLEY

The regular monthly meeting of the Lehigh Valley Section of the AMERICAN

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WELDING SOCIETY was held at the Hotel Bethlehem, Bethlehem, Pa., on Monday, December 6th, with Chairman H. W. Lawson presiding. This was a joint meeting of the AMERICAN WELDING SOCIETY and the American Society of Civil Engineers.

The speaker of the evening was LaMotte Grover who is Structural Welding Engineer, Applied Engineer Department, Air Reduction Sales Co., and a member of the Special Subcommittee on Welding of the American Bureau of Shipping. Mr. Grover's topic, "Fabrication of Ships and Buildings," was illustrated with lantern slides. Mr. Grover presented typical welding procedures and designs of welded joints used in ship work. He also touched on the prominent part welding will play in postwar work.

The next scheduled meeting of the Section will be held at the Hotel Bethlehem on Monday, February 7th, at which time Dr. J. W. Miller of the Reid-Avery Co. will speak on "Welding Electrodes."

LOUISVILLE

Dinner was served to approximately 150 members and guests at the Louisville Section's meeting at the Seelbach Hotel on November 30th.

R. E. Fritsch, Vice-President of Tube Turns, Inc., acted as Master of Ceremonies.

A humorous monologue by Mr. Howard, former old-time minstrel, was enjoyed by an appreciative audience.

Dr. H. C. Boardman, Director of Research, Chicago Bridge & Iron Co., Chicago, Ill., was introduced by Mr. Fritsch.

His topic—"Locked Up Stresses in Mild Steel Structures."

Dr. Boardman gave a very interesting and instructive reading. He had the command of a very attentive group, the majority of whom are employed on ship construction.

He was very generous in answering questions, not only about ship plates but pressure vessels, and had a very unique way of drawing questions from the audience.

The Louisville Section was indeed fortunate in having Dr. Boardman as a speaker.

Mr. David Arnott, President of the American Welding Society and Vice-President and Chief Surveyor of the American Bureau of Shipping, will be guest speaker at the Dinner Meeting, January 18, 1944. Mr. Arnott's subject will be "Problems in Ship Welding."

MILWAUKEE

The regular monthly meeting of the Milwaukee Section was held on November 19th at Cudworth Post, American Legion. An after-dinner talk "Your Brother's Brother" was given by Z. J. Zaiser, President, Ampco Metal, Inc. The welding address "Metallurgy of Welding" was presented by Robert Schroder of the Great Lakes Steel Corp. Mr. Schroder's talk covered the welding of alloy steels.

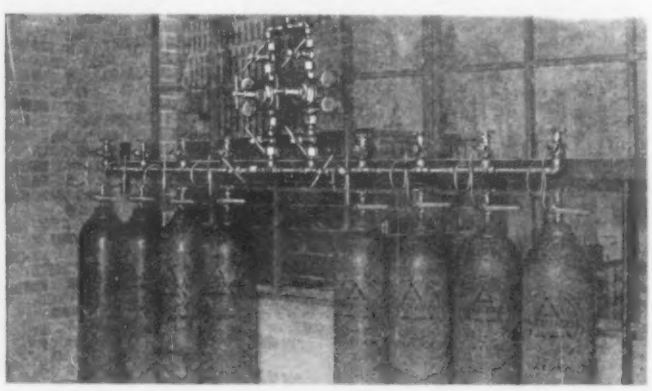
NEW JERSEY

The November meeting of the New Jersey Section was held on the 16th at the Essex House, Newark. Dinner in the Starlight Terrace preceded the meeting. "Changeover from Riveted to Welded Construction of Light Combat Tanks" was the subject of John W. Sheffer's talk. Mr. Sheffer is General Electrical Engineer at the American Car and Foundry Co. Fabrication, joint design and welding were discussed.

NEW YORK

On Wednesday, November 17th, the New York Section held a panel meeting with the Metropolitan Section of the American Society of Mechanical Engineers at the Engineering Societies Building. Technical chairman for the evening was Edwin B. Ricketts, Consolidated Edison Co. of New York, Inc.

Speaker for the evening was Orville T. Barnett, Production Engineer, Metal & Thermit Corp., New York. Title of Mr. Barnett's address was "Arc-Welding Electrodes—Their Coatings, Applications and Storage." Mr. Barnett discussed the



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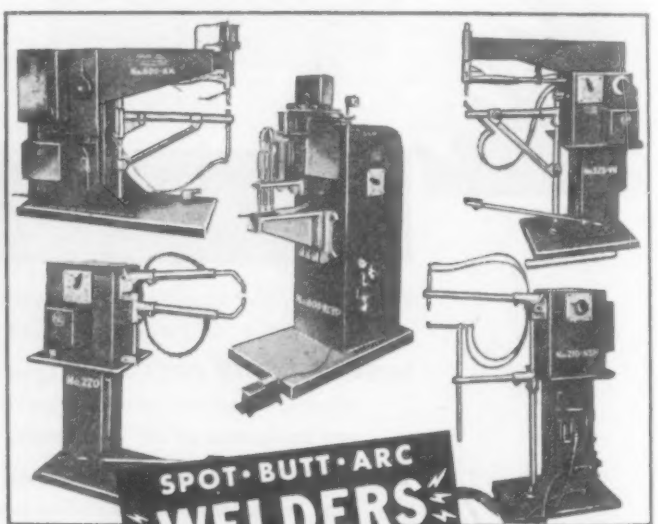

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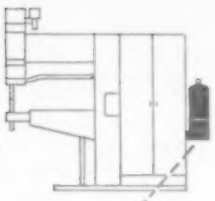

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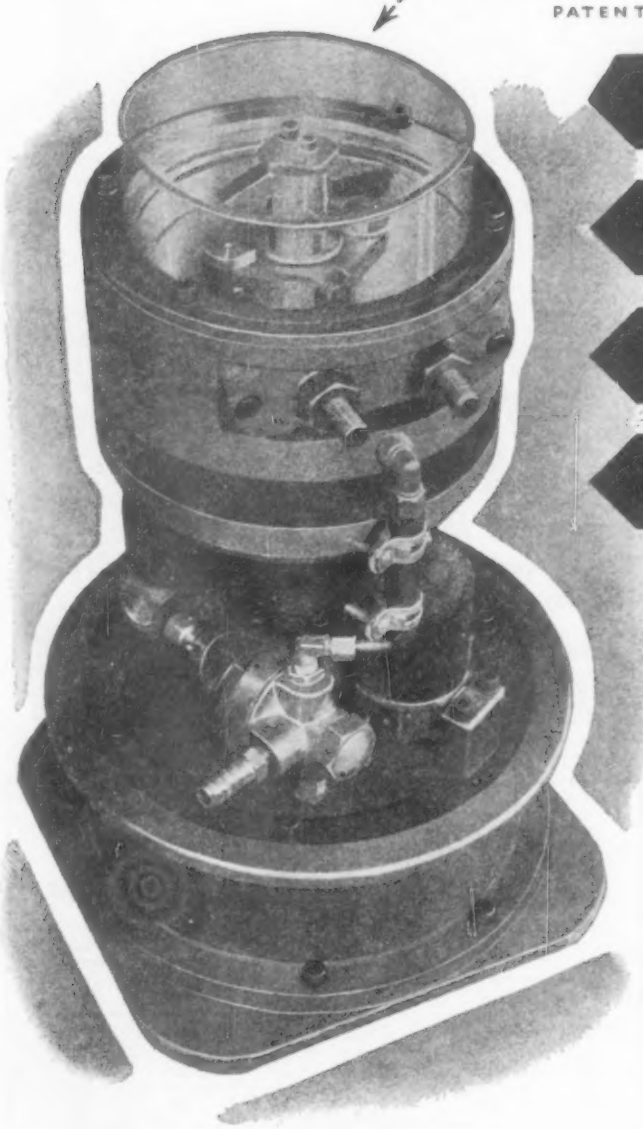

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reasons for the various types of arc-welding electrodes and explained where each should be applied in order to obtain the best results. He described briefly the contents of electrode coatings, the different weights and thicknesses employed and the effect of each on the weld. The importance of proper storage of electrodes was also covered. Mr. Barnett illustrated his very interesting paper with numerous lantern slides.

The evening opened with a half-hour Question and Answer period conducted by H. O. Klinke, Republic Aviation Corp., Farmingdale, New York. At the conclusion of the evening, a sound and color motion picture, "Fabricated Stern-Frame Thermit Welding" was shown through the courtesy of Metal & Thermit Corp., New York.

NORTHERN NEW YORK

The program for the coming meetings of the Northern New York Section is as follows:

Thursday, January 27th—General Meeting of Coordinated Societies. Subject to be announced later. T. B. Jefferson, Editor, *The Welding Engineer*.

Thursday, February 24th—Subject and speaker to be announced.

Thursday, March 23rd—"Welding in the Aviation Industry," by H. O. Klinke, Senior Welding Engineer, Republic Aviation Corp.

Thursday, April 27th—R.P.I., Troy, N. Y. Subject and speaker to be announced.

Thursday, May 25th—Annual business meeting.

NORTHWEST

"Low Temperature Brazing" was the subject of M. C. Robbins' talk at the November 16th meeting held at Coffman Memorial Union, University of Minnesota. Mr. Robbins is Manager of Handy & Harman, Chicago, and is recognized as one of the foremost authorities in the fields of silver solders and low melting point silver alloys. Mr. Robbins illustrated by slides the use of silver on various war jobs, and also made an actual demonstration of brazing various metals together, showing how the silver brazing alloy works.

Through the courtesy of W. M. Cordner, Sales Manager of the Northern Pump Co., there was shown the company's film "Precision Naval Machinery for Victory."

OKLAHOMA CITY

The November meeting of the Oklahoma City Section of the AMERICAN WELDING SOCIETY was held on the evening of November 11th, at the Biltmore Hotel. The speaker of the evening was W. S. Loose, Metallurgist for the Dow Chemical Co., Midland, Mich. Mr. Loose used a film sponsored by the Dow Chemical Co. as a basis for his talk. This film covered in detail the entire procedure for the producing and refining of magnesium. The electrolytic refining of the salts obtained from artesian wells in Michigan was quite interesting, as were the precautions necessary in working this metal as compared to other metals of manufacturers. As might be expected, the majority of the uses shown for this metal were in connection with war effort aircraft. Much discussion was had from the attendance, particularly as regards the technique and precautions to be used in welding magnesium products.

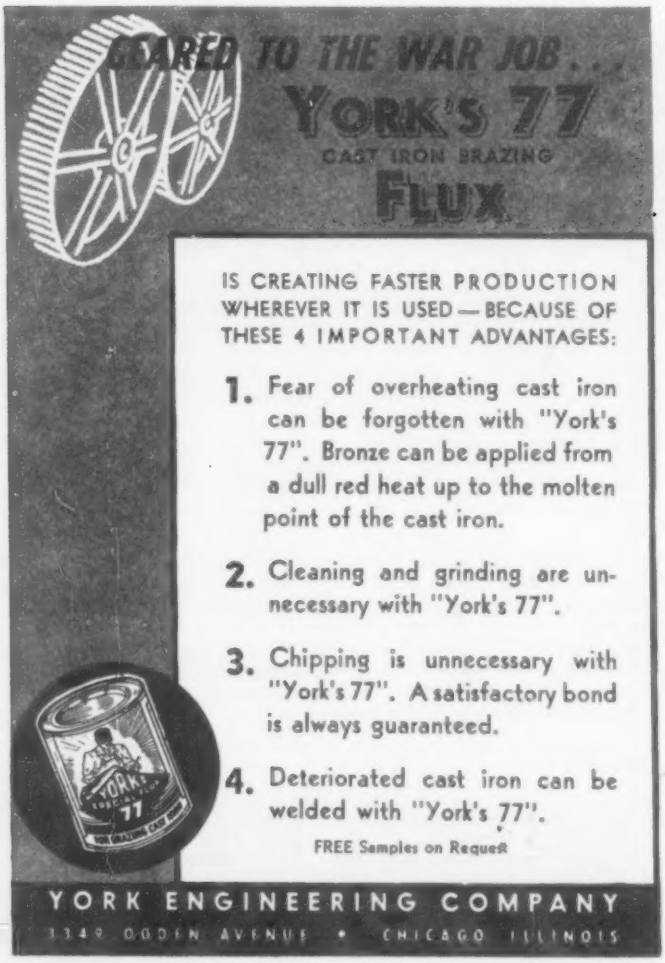
This meeting was well attended by local members, and in addition, a number of guests from the local aircraft manufacturing and Army repair groups were present.

PHILADELPHIA

The Second War Production Panel Discussion was held on Friday, December 3rd, at the Engineers Club Junior Board Room. Harry Irrgang, Superintendent, W. K. Mitchell Co., was the Chairman. E. R. McClung, Welding Engineer, The New York Shipbuilding Corp., and A. J. Raymo, Welding Engineer, The Baldwin Locomotive Works, spoke on the subject "Causes of Failures and Porosity in Welds."

PITTSBURGH

The November 17th meeting of the Pittsburgh Section was addressed by Dr. A. B. Kinzel, Chief Metallurgist, Union Carbide & Carbon Research Labs., New York. Dr. Kinzel's talk, "Welda-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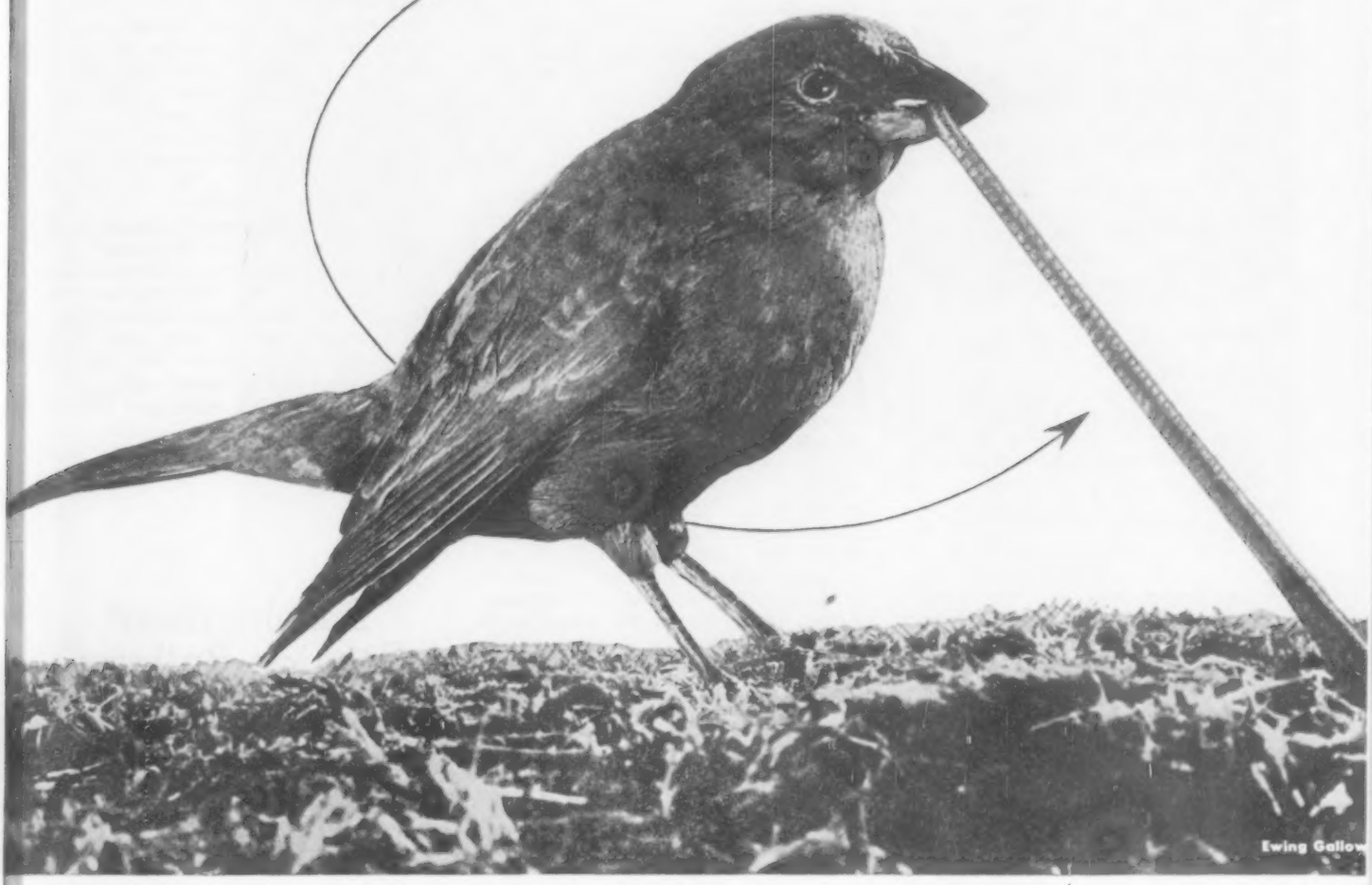

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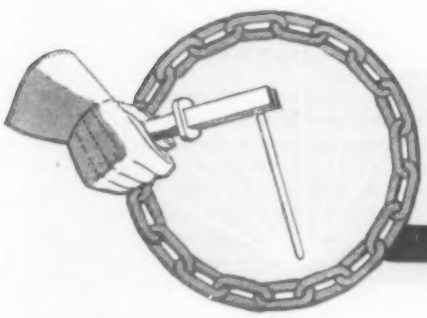

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bility of Steel," dealt with various factors affecting the behavior of steel on welding. As a separate feature a 15-min. film covering principles and applications of the flame hardening process was shown.

PUGET SOUND

The Puget Sound Chapter held their monthly meeting at the Gowman Hotel on Dec. 1, 1943. Due to the main speaker having to go East, a substitute program was presented as follows:

Film by Linde Air Products Co., "Construction and Operation of Acetylene Torch, Gages and Tanks."

Film by Alcoa on "The Welding of Aluminum."

The principal speaker was Jerry E. Martin, Processing Engineer for the Boeing Airplane Co. Mr. Martin gave an exceptionally interesting talk on the welding processes used in the Boeing plant.

ROCHESTER

The regular monthly meeting of the Rochester Section was held on December 2nd. Dinner in the Rush Rhees Library Cafeteria of the University of Rochester preceded the meeting, which was held in the Lower Strong Auditorium of the University. R. David Thomas, Jr., Director of Research and Engineering, Arcos Corp., spoke on the subject "Welding of Air-Hardenable Steels." Mr. Thomas, a pioneer in the development of austenitic electrodes for welding air-hardenable steels, discussed the problems encountered in welding these steels.

ST. LOUIS

A Welding Symposium held by the St. Louis Section on November 23rd and attended by 47 welding engineers, is believed to be probably one of the most worth-while activities, outside of the regular meetings, held by the Section. The success of this Symposium was so great that it has been tentatively planned to have two more such meetings during the year. Among those who attended this meeting were representatives of the shipbuilding industry, aircraft, motor manufacturers, refineries, steel casting manufacturers, tank fabricators, structural iron fabricators, etc. The following is an outline of the Symposium:

Round Table Discussion on Arc-Welding Design and Practices

1. Fundamental advantages of rolled steel—arc-welded design.
2. Design considerations in conversion to arc welding.
   (*a*) Start with small simple parts not requiring elaborate shop equipment.
   (*b*) Design problems in more complicated structures.
3. Designing for ease of fabrication.
   (*a*) Metallurgical factors affecting design such as, distortion, hardness, inherent cracking, etc.
   (*b*) Accessibility and positioning.
   (*c*) Sequence of welding and procedure control.
4. Economic considerations in design.
   (*a*) Wide use of excessive welding.
   (*b*) Preparation and fit-up for welding.
   (*c*) Specification of rod diameters and heats.

SYRACUSE

Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corp., was the guest speaker at the December 9th meeting held in the Museum of Fine Arts. Mr. Bibber's subject was "The Elements of Welding Design."

WASHINGTON, D. C.

The second meeting of the '43-'44 season of the Washington Section was held November 23rd at the Pepco Auditorium. An enthusiastic audience thoroughly enjoyed the Sections first Welding Question Bee. W. E. McKenzie, B. J. Brugge, C. E. Jackson, R. A. Mansfield, W. A. Haile and G. A. Ellinger, representatives of the Naval Gun Factory, Lincoln Electric Co., Naval Research Lab., Southern Oxygen Co., War Production Board and the Bureau of Standards, respectively, ably and in good detail answered the wide variety of questions put to them.

The difficulty of welding Navy "M" bronze was expressed and methods such as silver soldering and brazing were recommended for overcoming the troubles. A limit of 1% lead in the bronze would permit the satisfactory arc welding of the metal with no difficulty from lead sweating.

An excellent discussion on fillet design and properties by Mr. Brugge brought applause from the audience. The deep fillet technique was explained at length in answer to a question pertaining to the strength of $^3/_8$-in. fillets.

How the chemical composition of steel affects the weldability was covered by a lengthy discussion involving the current definitions of weldability. Many of the elements such as carbon, manganese, molybdenum, chromium described as the chiefly concerned elements, nickel, copper, silicon as less injurious and sulphur and phosphorus as offenders were reviewed. The role of inclusions was mentioned.

After the Question Bee a lengthy moving picture, "Japan, Our Common Enemy," was shown. Ex-Ambassador Drew was film narrator and the three sections of film furnished an excellent insight into the mental, physical and spiritual make-up of our enemy and his preparations for the war on his neighbors and the rest of the world.

WESTERN MASSACHUSETTS

In opening the meeting of the Western Massachusetts Section on November 29th, at the Holyoke Trade School, the chairman, Mr. Emery, welcomed 93 members and guests in attendance. Reports were heard from Mr. Hill of the program committee and Mr. Stray of the membership committee. Under old business the matter of technical papers was discussed. It was pointed out that papers had been received from two members and that the closing date for the first contest period was Dec. 20, 1943.

Proceeding to the technical part of the meeting, Mr. Emery introduced A. K. Phillippi, Manufacturing Engineer in Metal Joining at the Westinghouse Electric and Mfg. Co. Illustrating his talk with about 20 actual samples of furnace brazing, Mr. Phillippi covered the subject very vividly as shown by the interest of the membership. The various aspects discussed were preparation of joints, time cycles, jigging, metals used, atmosphere, strength of finished product and future prospects for the process.

At the conclusion of a short question period Mr. Emery expressed the appreciation of the group to Mr. Phillippi for his splendid presentation.

Following a brief recess, a sound movie titled "How to Weld Aluminum" was shown through the courtesy of the Aluminum Co. of America. This was found to be a highly commendable demonstration of methods used to weld and braze aluminum and its alloys. Electric arc, oxyacetylene and resistance welding were shown, as well as hand and furnace brazing.

This very successful meeting was closed at 10:15 P.M.

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BOARD OF DIRECTORS

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List of New Members

November 1 to November 30, 1943

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Ragan, W. J. (B), 2311—10th Ave., S., Birmingham, Ala.

BOSTON

Briggs, William M. (C), 63 Vincent St., S. Portland, Me.
Brummitt, Parmenter W. (C), 49 Wall St., Quincy, Mass.
Drew, Harry S. (C), Bay Rd., Sharon, Mass.
Haines, Glenn E. (C), Pickett St., S. Portland, Me.
Kimball, Gerald W. (C), 28 Nevens St., Portland, Me.
Pace, Harold F. (C), 306 Broad St., E. Weymouth, Mass.
Raleigh, John S. (B), Randolph St., Canton, Mass.
Taylor, Stephen M. (C), Box 2185, S. Portland, Me.

CANADA

Greene, R. L. (C), 10173—98th St., Edmonton, Alberta, Canada.

CHICAGO

Gilson, H. B. (C), 11503 S. Lothair Ave., Chicago, Ill.
Nichols, Wm. W. (C), 2727 Ross Ave., Highland, Ind.
Robinette, C. B. (C), 2025 S. 23rd Ave., Broadview, Ill.
Strothman, E. P. (B), 520 N. Michigan Ave., Room 324, Chicago 11, Ill.

CINCINNATI

Beaver, Clyde R. (C), 423 E. Third St., Cincinnati 2, Ohio.
Long, J. M. (C), Hartford Steam Boiler Insp. & Ins., 190A Carew Tower, Cincinnati, Ohio.

CLEVELAND

Bouffard, Donald E. (C), 1520 Lakefront Ave., Cleveland, Ohio.
Eichhorn, Edward (C), 12705 Woodside Ave., Cleveland, Ohio.
Schlabach, Capt. R. P., U.S.N. "RET." (B), The American Shipbldg. Co., 1410 Terminal Tower Bldg., Cleveland 13, Ohio.
Shane, Michael S. (B), 9304 Amesbury St., Cleveland, Ohio.
Stenz, Rolland E. (B), 830 Chalker St., Akron, Ohio.

DETROIT

Adamek, William E., Jr. (C), 22432 Bayview Dr., St. Clair Shores, Mich.
Bezoff, Michael (C), 6315 Steadman St., Dearborn, Mich.
Cantalin, John F. (C), 2333 Linwood Ave., Royal Oak, Mich.
Ford, A. R. (C), 424 Book Bldg., Detroit, Mich.
Kessler, Chas. A. (C), 11759 Promenade, Detroit 5, Mich.

HAWAII

Brush, George W. (B), P. O. Box 405, CHA-3, Honolulu 62, Hawaii.
De Thomasis, Domenic (C), Bldg. S1, 800—16th St., CHA-3, Honolulu 60, T. H.
Dick, C. A. (B), 402—10th St., Naval Housing, Honolulu 50, Hawaii.
Hawkins, William A. (C), 247-C Beach Walk, Honolulu 20, T. H.
High, Drexel P. (C), 320 Leuters St., Honolulu 37, T. H.
Hinnah, Mayburn Wm. (C), Valley, Neb.
Hohwill, Claude N. (B), 158 Poo Poo Pl., Lauikai, Honolulu, Hawaii.
Lee, Woodrow W. (C), 3611-A Maunalei Ave., Honolulu, Hawaii.
Rooth, Edward T. (B), 245A Saratoga Rd., Honolulu, T. H.

INDIANA

Heck, Donald (C), 167 West 4th St., Sheridan, Ind.
Osterhous, Carl S. (B), Engineering Sales Co., 621 N. Illinois St., Indianapolis 4, Ind.

KANSAS CITY

Brigham, R. W. (C), Welding Equipment Supply Co., 1617 Walnut St., Kansas City, Mo.
Freeman, L. A. (C), 524 Brotherhood Block, Kansas City, Kan.
Rambo, C. W. (C), 446 State Ave., Kansas City, Kan.

LEHIGH VALLEY

Astleford, Thomas (B), Tippett & Wood, Phillipsburg, N. J.
Basham, Alfred James (C), 718 George St., Throop 12, Pa.
Becker, R. W. (B), Tippett & Wood, Phillipsburg, N. J.
Epstein, Samuel (C), Dev., & Res., Dept., Bethlehem Steel Co., Bethlehem, Pa.
Dommes, Louis F. (C), 1026 Froude Ave., Scranton 5, Pa.
Fox, Sidney (C), Bethlehem Steel Co., Bethlehem, Pa.
Hooper, Harry (B), Tippett & Wood, Phillipsburg, N. J.
Hopkins, Fay E. (C), 84 Barnum Pl., Wilkes-Barre, Pa.
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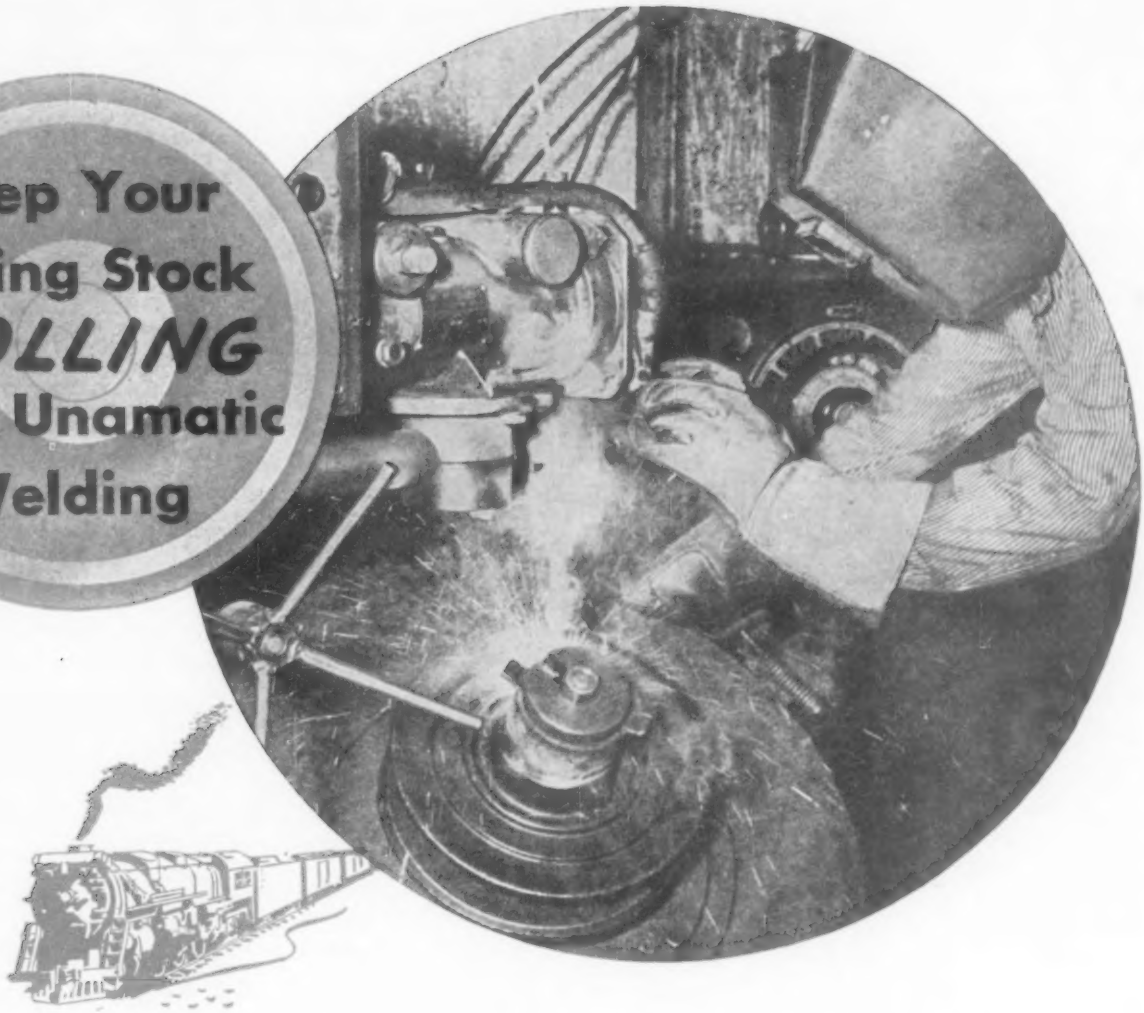

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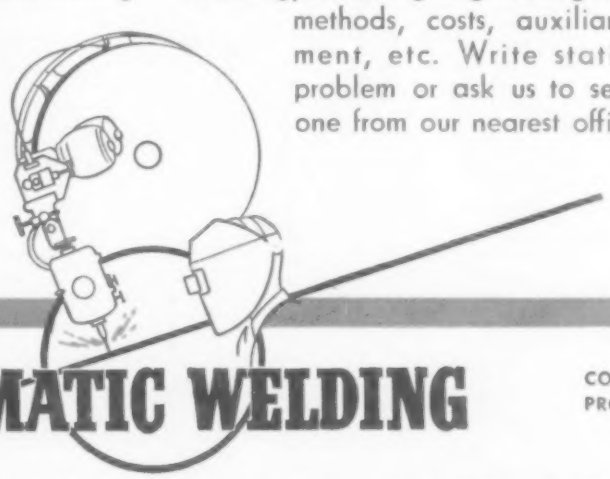

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